

**MAKERERE**



**UNIVERSITY**

**EPIDEMIOLOGY OF *TAENIA SOLIUM* CYSTICERCOSIS  
IN THE PIG VALUE CHAIN IN UGANDA**

**BY**

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## DECLARATION

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## **DEDICATION**

To my late brother Mboizi Peter who was unable to witness our life dream come to pass.

To my wife Josephine and two wonderful boys Kiganira Solomon, Kungu Shalom. My dad; Christopher.Kiganira Gabengere, mum; Phery Nakayenze.Gabengere and the whole family (Anthony, Sarah, Juliet, Annet, Isaac, Aidah, Andrew, Dan, Evalyn, Christine).

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## **LIST OF ABBREVIATIONS**

A4NH	Agriculture For Nutrition and Health
AP	Apparent Prevalence
ASARECA	Association for Strengthening Agriculture Research in Eastern and Central Africa
CDC	Centre for Disease Control
CSF	Cerebral Spinal Fluid
CT	Computerised Tomography
DAAD	Germany Academic Exchange program
DALYS	Disability Adjusted Life Years
FAO	Food Agricultural Organization
GPS	Global Positioning System
ILRI	International Livestock Research Institute
ITFDE	International Task Force for Disease Eradication
KCCA	Kampala City Council Authority
MAAIF	Ministry of Agriculture Animal Industry and Fisheries
NCC	Neurocysticercosis
OIE	World Organization of Animal Health
PC	Porcine Cysticercosis
WHO	World Health Organization

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## PREAMBLE

This study has been presented as a paper based thesis and it has seven chapters.

Chapter one constitutes a general introduction of the study. In this section, a background, problem addressed, justification, objectives, hypotheses tested and ethical considerations are explained. A general description of the materials and methods used in the study has been done here. However, a detailed explanation of the methodology followed to answer each objective has been presented in the respective chapters.

In chapter two, literature review on taeniosis-*T.solium* cysticercosis is presented. An in-depth comparative analysis of literature on disease situation and predisposing factors in selected economically struggling countries with a growing small holder pig industry was done. Transmission, methods of diagnosis and employed control strategies of *T. solium* infection in pig and human populations in these countries are also discussed. The major gaps identified in the review included scanty up to date information on porcine cysticercosis prevalence with hardly any reports on the condition in humans in most developing countries. Factors affecting pattern of the infection and how they interact at the different levels of the pig value chain have not been exhaustively studied. Information on socioeconomic impact is inadequate and not current.

Chapter three presents findings of a case study on spatial distribution of pork outlets and existing potential for transmission of food-borne infections in Kampala district, Uganda. The aim of the study was to map the distribution of pork retail outlets as well as assess their role in food borne disease transmission.

Chapter four reports the seroprevalence of *T. solium* cysticercosis in pigs in Masaka, Mukono and Kamuli districts. Up to 1185 pigs were sampled and their sera tested for presence of *T. solium* cysticercosis antigen using the HP10 and the B158/B60 Antigen-ELISA tests.

Chapter five describes the risk factors of the disease assessed in the 3 districts using a household questionnaire and a pig biodata checklist. Significant association between the risk factors and *T. solium* cysticercosis were tested by calculation of odds ratios and are presented here.

In chapter six, findings of perceptions and practices of farmers regarding taeniosis, human cysticercosis and porcine cysticercosis in Kamuli, Masaka and Mukono districts are presented.

In chapter 7 an overall discussion of the findings and limitations of the study has been done. Recommendations of control strategies with regards to the findings obtained in the study as well as future research areas are also suggested.

## EXECUTIVE SUMMARY

A study was done to assess the epidemiology of *T. solium* infection in the pig value chain in Kamuli, Mukono, Masaka and Kampala districts of Uganda. The infection affects swine as porcine cysticercosis, humans as taeniosis, and human cysticercosis. The larval stage of the pork tapeworm, generally referred to as *T. solium* cysticercosis, has for decades been responsible for lowering economic productivity when it affects pigs and direct human health defects. This study extensively assessed the disease situation in pigs and provide baseline data which could set a platform for appropriate disease control in humans and pigs.

In Kampala district, the demand for pork was high and lack of meat inspection for most pork presented a risk. Having a public health certificate was an important predictor of good practices.

Serum samples from 1185 pigs in Masaka, Mukono and Kamuli districts were tested for the presence of *T. solium* cysticercosis antigen using the HP10 antigen-ELISA (Ag-ELISA) and the ApDia Ag-ELISA assays. Using parallel interpretation of the two tests showed lower levels of observed prevalence of *T. solium* in rural production systems (10.8%) compared to urban (17.1%). Maximum Likelihood Estimation for evaluating assays in the absence of a gold standard, using TAGS on the R platform, estimated the true sero-prevalence to be lower in rural production systems, 0.0% [0.0-3.2%; 95% confidence interval (CI)] than in urban production systems, 12.3% (4.2-77.5% CI). When the sensitivity/specificity (Se/Sp) of the assays were estimated, assuming conditional independence of the tests, HP10 Ag-ELISA was more sensitive and specific [(Se=53.9%;



10.1-100% CI), (Sp=97.0%; 95.9-100% CI)] than the ApDia assay [(Se=20.2%; 1.5-47.7% CI), (Sp=92.2%; 90.5-93.9% CI)]. The HP10 Ag-ELISA test had higher sensitivity (64.9%) and lower Specificity (92.2%) compared to B158/B60 Ag-ELISA test (Sensitivity=35.4%, Specificity=95.9%). By assuming conditional independence of the two tests, the estimated true prevalence was 15.8%.

There were significant associations of *T. solium* cysticercosis with the exotic and crossbred pigs, unprotected water sources, not boiling drinking water and homesteads with family members who are unable to use latrines. Most farmers in Masaka, Mukono and Kamuli districts had an idea about the disease but could not link taeniosis with human cysticercosis and porcine cysticercosis which has made eradication of the condition difficult.

# CHAPTER ONE

## GENERAL INTRODUCTION

### 1.1 Background of study

Porcine cysticercosis is a parasitic condition caused by larval stages (cysts) of a pig tapeworm, *T. solium*. The infection affects humans and pigs (Ngowi *et al.*, 2010; Pondja *et al.*, 2010; Praet *et al.*, 2010; Willingham, *et al.*, 2010). They are infected when they ingest *T. solium* eggs in food and water, hatching into oncospheres that penetrate the intestinal lumen, migrating to different body tissues like the brain and muscles where they form cysts (Carabin *et al.*, 2009; Morales *et al.*, 2010; Praet *et al.*, 2010). *Taenia solium* cysts occur in pigs without developing into a clinical condition because they are usually slaughtered before the infection becomes eminent. However, presence of cysticercosis in pigs results in farmers incurring losses due to condemnation of infected carcasses in areas where meat inspectors are strict (Mutua *et al.*, 2007; Praet *et al.*, 2010; Zoli *et al.*, 2003). This is because undercooked infected pork when consumed increases the risk of taeniosis that maintains *T. solium* infection in the human population (Nsadha *et al.*, 2010). Presence of cysticercosis in pigs especially those under free range management has therefore been suggested as an indicator of occurrence of the infection in humans. This is usually the case in the rural small holder pig keeping communities of Uganda where pigs move unrestricted and ingest contaminated materials (Morales *et al.*, 2008; Pondja *et al.*, 2010; Waiswa *et al.*, 2009; Willingham *et al.*, 2010).

In humans however, a clinical manifestation of the infection will occur depending on the tissues of the body affected, number of cysts, size of cysts and the immune response elicited in the affected body. The most detrimental effect of *T. solium* cysticercosis is experienced when the larvae invade and lodge in the brain tissues causing neurocysticercosis that manifests as epileptic seizures and it has been recognized as a leading cause of epilepsy in developing countries like Uganda (Garcia *et al.*, 2010; Phiri *et al.*, 2003; Waiswa *et al.*, 2009).

## **1.2 Statement of the problem**

Some studies of the seroprevalence of porcine cysticercosis had been done in Uganda. Nsadhha and others (2010) reported a seroprevalence of 8.6% in the South-Eastern districts of Kaliro and Kamuli. Waiswa and other (2009) found seroprevalence of 4-12.9% in the same districts. However, the magnitude of the disease in the main pig producing districts of Masaka, Mukono and Kamuli as well as risk factors associated with transmission and maintenance of *T. solium* infection along the pig value chain in Uganda was not well documented. The practices associated with the maintenance of the life cycle of the *T. solium* condition at consumer level of the pig value chain were also not documented. Therefore this study elucidated these factors as well as the magnitude of the porcine cysticercosis along the pig value chain.

## **1.3 Justification of study**

Pig production in Uganda has experienced a tremendous growth over the recent years, with an estimated total herd of up to 3.2 million pigs according to the 2008 National Livestock Census report (MAAIF, 2011). This growth has resulted from increased demand for pork and pork products by consumers, with the consumption/capita of pork in Uganda being estimated at 3.4 Kg/person/year. The good attributes of pigs like high fecundity, high feed conversion rate, early maturity, short generation interval, minimal space requirements have made pigs a priority source of livelihood for over 1.1 million rural poor in the rural and peri-urban communities in Uganda (FAO, 2013).

Despite the positive aspects described above, there is a high prevalence of *T. solium* cysticercosis in pigs in Uganda. This puts humans consuming pork at a high risk of getting infected with taeniosis and neuro-cysticercosis. Unlike previous studies, this study assessed factors that have led to persistence of porcine cysticercosis along the pig value chain hence setting a ground for designing the most appropriate control plan for this condition in Uganda. The control plan recommended in this thesis can be used by key stakeholders (policy makers, public health workers, extension workers, farmers, local communities) for controlling the condition.

#### **1.4. Objectives of the study**

The overall objective of this study was to ascertain the risk factors of *T. solium* cysticercosis along the pig production and marketing value chain in Uganda.

The specific objectives included;

- I. Determine spatial distribution of pork outlets and potential for transmission of food borne infections in Kampala district.
- II. Determine seroprevalence of *T. solium* cysticercosis in pigs in Masaka, Mukono and Kamuli districts
- III. Identify and assess the risk factors associated with occurrence of *T. solium* cysticercosis.
- IV. Assess the perceptions and practices of farmers on *T. solium* cysticercosis and its control.

### **1.5 Research questions.**

- I. What is the seroprevalence of *T. solium* cysticercosis infection in Kamuli, Mukono and Masaka districts?
- II. What is the distribution of pork outlets and potential for transmission of food-borne infections in Kampala district?
- III. Do factors influencing the occurrence of *T. solium* cysticercosis in Kamuli, Mukono and Masaka districts exist?
- IV. What are the perceptions and practices of farmers on *T. solium* cysticercosis and its control?

### **1.6 General description of materials and methods of study**

#### **1.6.1. Study sites.**

A cross-sectional survey was conducted between April and August, 2013 in Masaka, Mukono, and Kamuli districts in Uganda to determine the seroprevalence of *T. solium* cysticercosis in pigs. These study sites have been described in Table 1.1 and illustrated in Figure 3.1 in chapter three.

**Table 1.1:** Description of the study areas

District	Geographical location	Population (2012 Estimate)	Coordinates, Elevation and Land area
Kampala	Bordered by Wakiso District to the south, west and north and by Mukono District in the east	Total:1,659,600	Coordinates 00°19'N, 32°35'E) at an elevation of 1,200 m (3,900 ft)
Masaka	Bordered by Bukomansimbi District to the northwest, Kalungu District to the north, Kalangala District to the east and south, Rakai District to the southwest and Lwengo District to the west.	Total:251,600 Density:194.2/km <sup>2</sup>	Coordinates:00°22'S 31°42'E. Elevation :1,115 m (3,658 ft) Land:1,295.6 km <sup>2</sup>
Mukono	Bordered by Kayunga District to the north, Buikwe District to the east, the Republic of Tanzania to the south, Kalangala District to the southwest, Wakiso District and Kira Town to the west and Luweero District to the northwest.	Total:551,000 Density:293.9/km <sup>2</sup>	Coordinates:00 20N, 32 45E. Elevation:1,200 m (3,900ft) Land:1,875.1km <sup>2</sup>
Kamuli	Located in south-eastern Uganda, The district borders River Nile and Kayunga district in the west, Jinja district in the South, Iganga district in the Southeast, Kaliro District in the East and Soroti district and Lake Kyoga in the north.	Total:500,800 Density:321.6/km <sup>2</sup>	Coordinates of the district are:00 55N, 33 06E. Elevation:1,100 m (3,600 ft) Land:1,557 km <sup>2</sup>

## **Site selection process**

This study was carried out in the sites selected by the Smallholder Pig Value Chain Development (SPVCD) project implemented in Uganda by the International Livestock Research Institute (ILRI). The study districts were selected using the Geographical reference Information System criteria and stakeholder consultation. Sub-counties were suggested by stakeholders at district level and evaluated through ground-truthing (objective checklist). Selection of parishes and villages was based on value chain types and soft criteria provided by local partners. Details of the site selection process is described elsewhere (Ouma, *et al.*, 2014).

### **1.6.2. Sampling strategy.**

A proportional multistage random selection was carried out. The population of interest was all pig keepers in the three districts; the target population was all pig keepers in selected sub-counties; the sampling frame was a list of all pig farmers in the Sub-counties provided by Local Governments staff involved in the SPVCD activities. The study population included pig keepers selected for participation in the study. All random sampling was performed using a computer-generated random numbers. Selection of the villages was stratified based on the value chain domain described by the SPVCD project as: rural production for rural consumption (R-R), rural production for –urban consumption and urban production for urban consumption (U-U). The objective was to have all value chain domains represented in each district. The number of subjects selected

was proportional to the pig population in each village. The epidemiological unit was considered to be the farm. In each farm, one animal fitting the inclusion criteria was randomly selected and included in the survey. A pig biodata form and a structured questionnaire were administered to the owner of the farm to assess the predisposing factors of *T. solium* cysticercosis.

### **1.6.3. Sample size calculation.**

The sample size was calculated considering an infinite population (no recent census data) using the formula adopted from Thrusfield, 1995 as follows:

$n = [Z^2 P(1-P)]/d^2$  Whereas: n is the required sample size; Z is the multiplier from normal distribution (1.96) at a probability level of 0.05; P is the estimated prevalence which is 50% considering that there is no reliable prevalence data of *T. solium* cysticercosis in pigs in Mukono and Masaka districts Uganda; (1-P) is the probability of having no disease and d is the desired precision (5%). The level of confidence is set at 95% confidence interval. The sample size was calculated to be 384 farms in each district.

### **Criteria for inclusion**

Only pigs older than 2 months, not weak, able to stand through the bleeding process were selected. Sows which were pregnant or having litters less than 2 months old were also excluded from the study.

### **1.6.4. Collection of serum samples and analysis.**

Pigs were restrained by a field assistant using a snare and bled from the cranial vena cava using vacutainer needles and plain tubes. The blood samples were kept standing in an ice box at +4°C to ensure no agglutination occurred while in the field. At the laboratory,



blood was centrifuged to separate serum from whole blood. Serum was harvested into barcoded vials that were stored at  $-20^{\circ}\text{C}$  until processed. The serology assays work took place at the International Livestock Research Institute (ILRI) laboratories in Nairobi, Kenya.

#### **1.6.5. Serology.**

Analysis of serum for *T. solium* cysticercosis antigen was done using two serological tests, namely; HP10Ag-ELISA and B158C11A10/B60H8A4 (apDIA Cysticercosis) Ag-ELISA tests. These tests which detect the secretory and excretory products of the cysticerci were used to identify the pigs with viable infection so as to understand the level of transmission of the condition in the country (Alcobedes *et al.*, 2010). Limitation of the Ag-ELISA tests is that although some authors reported having detected antigens in a one viable cyst pig (tongue inspected), they are not appropriate in case of low infection in the pigs (Rodriguez-Hidalgo *et al.*, 2006). To minimize such inconsistencies, the same serum samples were analysed using 2 tests then an estimation of true prevalence done using the parallel interpretation criteria as described by Dohoo and others(2009). The tests were conducted on the same serum samples, beginning with HP10 Ag-ELISA followed by B158C11A10/B60H8A4 after an interval of one month. The tests have been reported to cross-react with *T. hydatigena* which occurs in Uganda but had only been reported in goats and sheep. In Tanzania where it has been reported, its prevalence was low in pigs suggesting its influence on the outcome of these tests could be minimal ( Ngowi *et al.*, 2004; Venkata *et al.*, 2012).

### **The HP10 Ag-ELISA**

The antigens for *T. solium* cysticerci in the pig serum were detected using HP10 Ag-ELISA as described by Harrison et al (1989) . The reagents were supplied by Parkhouse (Spain) .Briefly:

A 10µg/ml solution of McAb-HP10 in coating buffer was prepared and 100µl of this was added to each of the wells of a flat bottomed Immulon 1 ELISA plate. The plate was then covered with cling film to prevent evaporation and incubated overnight at 4°C. The wells of the plate were washed out twice with washing solution (NaCL/Tween). 200µl of PBS/BSA/Tween was then added to each of the wells to block any non-reacted sites on the plate. The plate was left for 1 hour at room temperature to block.

The plate was washed 3 times with washing solution. The serum (or test samples) was added at 100µl/well and the plate covered with cling film and incubated for 1 hour at 37°C. The plate was emptied and the wells washed three times using washing solution and the biotinylated-McAb diluted 1:2,500 in PBS/BSA/Tween added at 100µl/well. The plate was then covered in cling film and incubated for 1 hour at 37°C and the washed as in steps 5 and 8. The Streptavidin Peroxiase conjugate diluted 1:10,000 (0.1µg/ml) in PBS/BSA/Tween was added at 100µl per well and the plate covered in cling film and incubated for 1 hour at 37°C. The plate was washed as in steps 5 and 8. 100µl TMB substrate was added and the plate incubated at room temperature for 15-30 minutes, checking that the background control wells remain negative. The reaction was stopped using sulphuric acid and the plates read in a spectrophotometer at a wavelength of 450 nm. The cut-off was calculated using a modified Student *t*-test (Sokal& Rohlf, 1981) programmed in MS Excel sheet, by comparing the optical density of each serum sample

with an average of 5 negative serum samples included in the plate and obtained from pigs without any history of cysticercosis at a probability level of  $P < .001$ . A serum sample was noted as positive when the ratio (optical density of test sample/optical density cut-off) was greater than 1.0.

#### **The B158C11A10/B60H8A4 Antigen- ELISA test**

The test, commercially available as apDia Cysticercosis Antigen (Ag) ELISA test was conducted as described by Dorny *et al* (2003). The reagents were procured from apDia diagnostics (Belgium). Briefly; 100µl positive control sample was added to the first well of the test strip, 100µl negative control to second well followed by 100µl of pre-treated serum samples into the other wells in duplicate. The plate was sealed with micro plate sealer and incubated for 15mins at 37°C shaking at 7-800rpm. The plate was then washed 5 times with 300µl of wash buffer in each well. The plate was then tipped out to remove excess fluid by blotting on absorbent paper. 100 µl of conjugate solution was added to each well and the plate and incubated 15mins at 37°C while shaking at 7-800rpm followed by washing. 100 µl of chromogen solution was added to each well and plate covered with silver foil to protect from sunlight and incubated for 15 minutes at room temperature; dark, not shaking.

The reaction was stopped using sulphuric acid and the plates read in a spectrophotometer at a wavelength of 450 nm with 630nm reference filter. The cut-off was calculated using a modified Student *t*-test (Sokal & Rohlf, 1981) programmed in MS Excel sheet, by comparing the optical density of each serum sample with an average of 5 negative serum samples included in the plate that were obtained from pigs without any history of

cysticercosis at a probability level of  $P < .001$ . A serum sample was noted as positive when the ratio (optical density of test sample/optical density cut-off) was greater than 1.0.

#### **1.6.6. Statistical analysis of data.**

A McNemar chi-square test for the correlation between the proportion of positive results for HP10 and ApDia assays was conducted and a simple comparison of number of positive tests used to hypothesize as to the level of independence of the tests. The two assays are not ‘gold standard’, as they do not have perfect specificity (i.e.  $Sp = 1$ ) or sensitivity (i.e.  $Se = 1$ ) (Enøe et al., 2000). In the absence of this gold standard test, Maximum Likelihood Estimation (MLE) (Dohoo, Martin and Stryhn, 2009), which can be used if at least two populations (rural and urban) have differing prevalence, was carried out using TAGS program on the R platform (Pouillot et al., 2002) to estimate and compare the seroprevalence of *T. solium* cysticercosis in pigs in the rural and urban production systems as well as the sensitivity and specificity of the assays, with bootstrapped 95% confidence intervals (1000 samples), assuming conditional independence for the tests.

### **1.7 Ethical Considerations of study**

The study was approved by the Research and Ethics Committee of the College of Veterinary Medicine Animal Resources and Biosecurity (COVAB) of Makerere University (Reference No: VAB/REC/13/104) and by the Ugandan National Council for

Science and Technology (UNCST) with reference number HS1477. Formal consent was obtained from the pig owners to participate in the study and to allow their pigs to be bled by them signing a consent form (copies in the appendix).

## **CHAPTER TWO**

### **A REVIEW OF EPIDEMIOLOGY OF *TAENIA SOLIUM* CYSTICERCOSIS AND PREDISPOSING FACTORS IN DEVELOPING COUNTRIES**

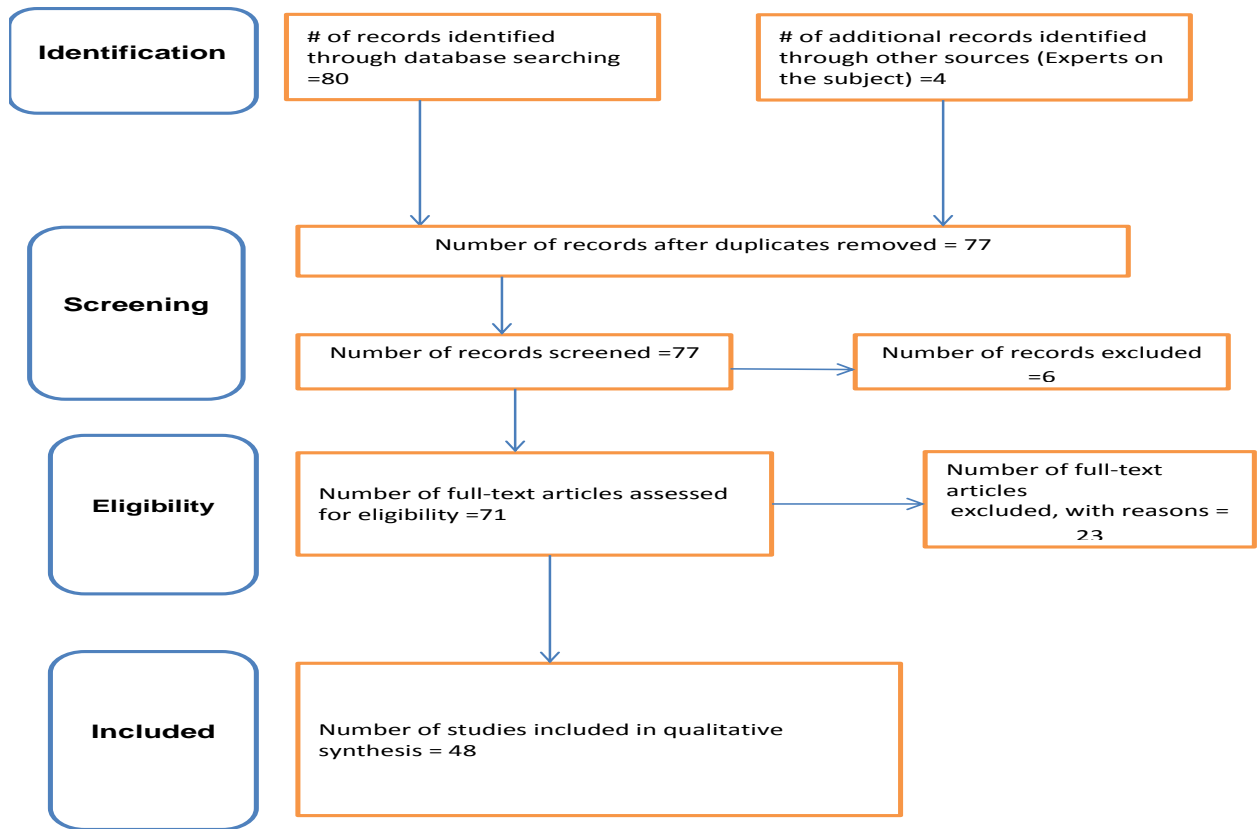
#### **2.0 Overview of *T. solium* cysticercosis**

*T. solium* cysticercosis a parasitic zoonosis caused by larval cysts of pig cestode. *T. solium* has received little attention for decades despite its traumatizing health and socio-economic impact (Boa *et al.*, 2006; Pondja *et al.*, 2010). In countries where this condition occurs, every case of cysticercosis in pigs has been estimated to result in a monetary loss of 194 Euro and 9 Disability Adjusted Life Years (DALYS) per 1000 persons per year are averagely lost (Ngowi *et al.*, 2010). With minimal or no constraints due to porcine cysticercosis experienced in the developed world, the condition remains a problem of the poor. About 70% of the world's rural poor are known to depend on livestock as their source of livelihood and have been reported to be the most prone to prevailing endemic zoonoses of today (World Bank, 2014). *T. solium* cysticercosis has been ranked third of the 13 identified endemic zoonoses implicated for causing most illnesses of poor livestock keepers; in addition to this has devastating socio-economic effects (Carabin *et al.*, 2009). With many health challenges affecting the rural-poor communities, priority has been given to the continuously emerging epidemics, leaving the condition uncontained (Grace *et al.*, 2012). In many developing countries, pig-keeping is undergoing rapid

expansion in response to the ‘livestock revolution’ that is, the rapidly increasing demand for animal source foods driven by urbanization, changing dietary preferences and increasing incomes (Grace *et al.*, 2012; Lekule and Kyvsgaard, 2003; Molyneux *et al.*, 2011; World Bank, 2014). These changes could be anticipated to influence the epidemiology of the disease. The objective of this review was to present recent information on cysticercosis epidemiology in the context of rapidly expanding pig systems in developing countries.

## **2.1 Approach of the review**

In this review, a detailed comparative analysis of literature from recent studies conducted in pig keeping communities of countries from Latin America, Asia and Africa was been done. Except The People’s Republic of China, the countries described here are among those defined by the World bank as developing ( World Bank, 2014). The review focused on information outside of the conventionally used databases. The search strategy involved entering key terms like “*T. solium* cysticercosis and taeniosis in developing countries, diseases of pigs communicable to man, parasites of public health importance, neglected tropical diseases, prevalence of epilepsy due to neurocysticercosis” in Google scholar, Mendeley, and Wikipedia internet search engines. Websites hosted by animal and human disease surveillance agencies such as WHO, FAO, OIE, and CDC were browsed for the latest updates posted regarding the *T. solium* condition. Figure 2.1 describes details of the search strategy used (Moher *et al.*, 2009).



**Figure 1:** A flow chart showing the methodology used to review the status of porcine cysticercosis in developing countries (Adopted from PRISMA Flow diagram by Moher et al 2009).

## 2.2 Findings

*T. solium* cysticercosis, a globally recognized public health concern, still remains a serious yet neglected condition among the world's poverty stricken populations. The condition caused by metacestode of *T. solium* (previously referred to as *Cysticercus cellulosae*) affects pigs and humans (WHO, 2014). The pig is the known primary intermediate host (causing porcine cysticercosis) and humans the definitive host (resulting in taeniosis) for this larval infection. Dogs have been reported as secondary intermediate hosts for the metacestode. Possibility of humans acting as accidental

intermediate hosts (leading to human cysticercosis) and pigs as secondary final host of this tapeworm infection has been described (Nakaya, 2002). Human cysticercosis becomes a life threatening situation when the metacestodes invade the brain tissues resulting in Neurocysticercosis (NCC) which is the leading known cause of epilepsy in human populations of the developing countries (Pondja et al., 2010). Details of the prevalence findings on *T. solium* cysticercosis in selected countries in Latin America, South East Asia and Africa are presented in Tables 2.1, 2.2, and 2.3. The tests in all the studies presented in Tables 2.1, 2.2 and 2.3 were serological ELISA tests except for Indonesia (Meat Inspection, MI) and Kenya (Tongue palpation, TP).

**Table 2.1:** Prevalence findings on *T. solium* cysticercosis of studies conducted from 2002-2013 in selected developing countries in Latin America.

Country (Area of study)	Prevalence in pigs % (Sample size )	Seroprevalence in humans with Epilepsy % (Sample size )	References
Mexico (Tetzdziz, Mexico city)	35(109)	12.2	(Morales & Martínez, 2010)
Bolivia	38.9	17	(Flisser, 2002)
Guatemala	14	17	(Flisser <i>et al.</i> , 2003)
Peru	75	24	(García <i>et al.</i> , 2010; García <i>et al.</i> , 2003)

**Table 2.2:** Prevalence findings on *T. solium* cysticercosis of studies conducted from 2002-2013 in selected developing countries in South- East Asia.

Country (Area of study)	Prevalence in pigs % (Sample size )	Seroprevalence in humans with Epilepsy % (Sample size )	References
India	Unknown	4.64(2500)	(Nitin et al., 2010)
Vietnam	0.9	5.3(303)	(Ito <i>et al.</i> , 2003;



			Somers <i>et al.</i> , 2006)
Indonesia (Papua-Jayawijaya)	77 <sup>MI</sup> (35)	29.2	(Ito <i>et al.</i> , 2003)
Cambodia	10.9	10	(Rajshekhar <i>et al.</i> , 2003)
P.R China	Unknown	0.58(96,008)	(Willingham <i>et al.</i> , 2010)
Phillipines	Unknown	24.6(497)	( Willingham <i>et al.</i> , 2010)

<sup>MI</sup>-Meat Inspection

**Table 2.3:** Prevalence findings on *T. solium* cysticercosis of studies conducted from 2002-2013 in selected developing countries in Africa.

Country (Area of study)	Prevalence in pigs % (Sample size )	Seroprevalence in humans with Epilepsy % (Sample size )	References
The Gambia (Western province)	4.8 (371)	0	Secka, <i>et al.</i> , 2010
Senegal ( Southern region)	6.4-13.2 (1,705)	Unknown	Secka <i>et al.</i> , 2010
Burkina Faso (Batondo, Pabre', & Nyonyogo)	Unknown	10.3(768)	Carabin <i>et al.</i> , 2009
Nigeria	20.5 (7,471,730)	0	Assana <i>et al.</i> , 2013
Cameroon (Northern region)	26.6 (398)	5(237)	Assana <i>et al.</i> , 2010; Elliott <i>et al.</i> , 2013
Democratic Republic of Congo (Kinshasa; Bas-Congo province)	38.4(498); 41.2 (158)	21.6	Kanobana <i>et al.</i> , 2011; Praet <i>et al.</i> , 2010
Rwanda(Southern region)	Unknown	21.8(215)	Rottbeck <i>et al.</i> , 2013
South Africa (Eastern Cape Province)	57 (261)	32.6 (273)	Krecek <i>et al.</i> , 2008
Zambia(Eastern region)	Unknown	14.5(817)	Mwape <i>et al.</i> , 2012
Mozambique (Angonia)	34.9(661)	Unknown	Pondja <i>et al.</i> , 2010
Tanzania (Mbulu district)	7.3 (784)	Unknown	Ngowi <i>et al.</i> , 2004

Kenya (Western region)	6.5 <sup>TP</sup> (33)	Unknown	Mutua <i>et al.</i> , 2007
Uganda (South-Eastern region)	8.5 (480)	Unknown	Waiswa <i>et al.</i> , 2009

<sup>TP</sup>-Tongue palpation

## 2.3. The transmission cycle of *T.solium* cysticercosis

### 2.3.1 Transmission of *T.solium* cysticercosis in pigs.

Pigs are infected when they ingest *T. solium* eggs in food and water, hatching into oncospheres that penetrate the intestinal lumen, migrating through the blood circulatory system and lymphatics to different body tissues where they form cysts (cysticerci) (Moher *et al.*, 2009; Molyneux *et al.*, 2011). Cysticerci establish preferably in active tissues like the brain, skeletal and cardiac muscles. This process takes about 8 weeks, with the cysticerci remaining viable for at least one year, and inflammatory reactions around the cysticerci sets in after (Assana *et al.*, 2010; Conlan *et al.*, 2009). This probably explains why *T. solium* does not develop into a clinical condition in pigs since with exception of sows; they are not usually kept for longer than a year before slaughter. All age groups can be affected however prevalence is significantly higher in pigs that are more than 4 months old (Boa *et al.*, 2006).

Porcine cysticercosis (PC) is amplified by factors that lead to environmental contamination with the *T. solium* eggs and those that expose pigs to this contamination. Such causal factors include open air defecation by human carriers, use of human waste as manure, careless disposal of untreated sewerage and exposure factors such as free range pig rearing, unprotected water and food sources. Presence of these risk factors correlates

with poverty levels of pig farming communities. This explains the global trend of PC with prevalence being highest in Africa, South East-Asia and least in Latin America (World Bank, 2014). Despite this, presence of cysticercosis in pigs results in farmers incurring losses due to condemnation of infected carcasses in a few areas where meat inspectors are strict (Carabin *et al.*, 2005; Krecek *et al.*, 2012). Presence of cysticercosis in pigs especially those under free range management has therefore been suggested as an indicator of occurrence of the infection in humans. This is expected in the rural small holder pig keeping communities of many developing countries where pigs move unrestricted and ingest contaminated materials (Lekule and Kyvsgaard, 2003; Murrell *et al.*, 2005; Willingham & Engels, 2006).

### **2.3.2 Transmission of taeniosis and *T.solium* cysticercosis in humans.**

Taeniosis usually occurs when humans eat undercooked or raw pork infected with cysticerci (Lekule and Kyvsgaard, 2003). Since *T. solium* cysticercosis has been reported to affect dogs, they are potential sources of human taeniosis in countries such as Korea, Vietnam, Indonesia and the People's Republic of China, where they are frequently eaten. Human populations in urban centres of developing countries who unknowingly consume dog meat disguised as beef are at risk too (Foyaca-Sibat *et al.*, 2009; Morales *et al.*, 2010).

The development process of a tapeworm involves the scolex evaginating and attaching to the mucosa with its double row of hooks and its four suckers in the upper third section of the small intestine, which is the duodenum-jejunum. The adult worm develops and starts

releasing gravid proglottids, the first expulsion taking place between eight to 12 weeks after infection. A few gravid proglottids are passed out in the host's faeces daily or two to three times per week ( Ngowi *et al.*, 2010). Although the tapeworm carriers experience minimal clinical defects, they play a pivotal role in the *T. solium* transmission cycle by shading adult worm segments packed with eggs into the environment. A contaminated environment becomes a source of infection for other humans and pigs that ingest it from food and water. The carriers are also a source of infection to themselves by autoinfection which can be due to reverse peristalsis (endogenous), or ano-oral contamination (exogenous) ( Krecek *et al.*, 2012; Praet *et al.*, 2010).

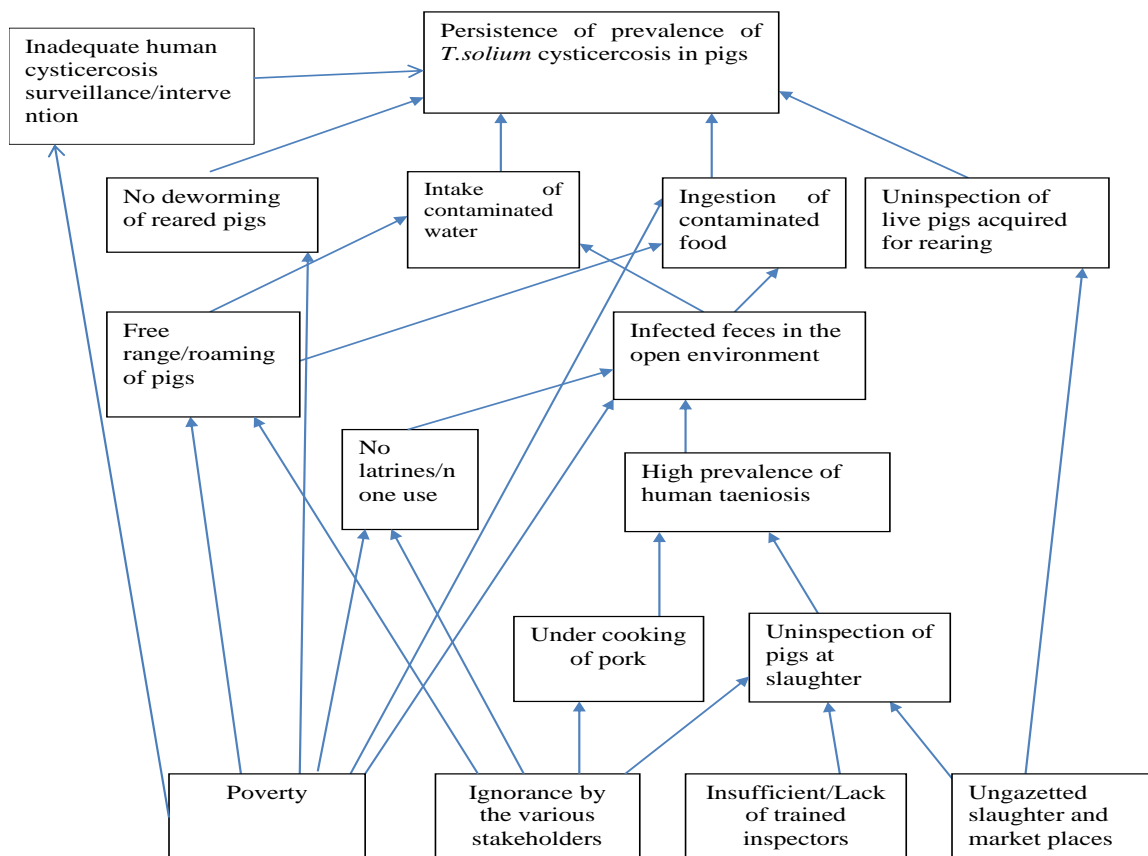
Human cysticercosis clinically manifests depending on the tissues of the body affected, number of cysts, size of cysts and the immune response elicited in the affected body. The most significant clinical defects have been reported to occur when the cysts lodge in the brain and the eyes thereby manifesting as epileptic seizures and eye defects (Garcia *et al.*, 2010; Rottbeck *et al.*, 2013; Zammarchi *et al.*, 2013).

The pattern of human cysticercosis in a population is determined by various factors responsible for environmental contamination like presence of tapeworm carriers in the vicinity. Other factors facilitate maintenance of this contamination and its exposure to the humans and they include; open air defecation, poor sewerage disposal, use of human waste as manure in horticulture, poor hygiene and sanitation, poor pig management practices as well as lack of awareness of the disease and its implications (Morales *et al.*, 2010). These factors have been noted to be high with increasing levels of poverty and hence the corresponding prevalence patterns that are varying in the different regions

described in the review (Tables 1 and 2).

#### **2.4. Risk factors associated with *T. solium* cysticercosis**

*T. solium* cysticercosis has been recognized to be a common occurrence in rural communities in the developing world. Various factors have been identified to be responsible for the spatial distribution and occurrence of this condition in humans and pigs. Such factors include; poor hygiene and sanitation practices in humans, rearing pigs by free-range and tethering, lack of awareness about the disease and its transmission, non-inspection of pigs before or following slaughter, age of pigs( García *et al.*, 2003; Murrell *et al.*, 2005; Sreedevi *et al.*, 2012). A conceptual framework describes in detail how these factors interact along the production and marketing chain in figure 2.2.



**Figure 2.2:** A conceptual analytical model for analysis of risk factors along the pig production and marketing chain in Uganda.

#### 2.4.1 Poor hygiene and sanitation practices

Poor hygiene and sanitation have been reported to play a key role in the transmission of *T. solium* cysticercosis in both humans and pigs. Poor hygiene practices like lack of hand washing with soap following visits to the latrines and before eating food, eating unwashed fruits and vegetables, drinking unboiled/untreated water result in humans ingesting the eggs of *T. solium* and causing porcine cysticercosis (Assana *et al.*, 2010; Murrell *et al.*, 2005). Poor sanitation in the households due to open air defecation, latrines

in poor conditions allowing pigs to access faeces increases the possibility of occurrence of the infection (Sreedevi *et al.*, 2012). Faeces deposited in the open environment are often washed into unprotected springs and wells contaminating the water sources hence posing a risk to both pigs and humans (Murrell *et al.*, 2005). Such a risk of contamination of food and water is high especially in rural communities with over 60% none/poor latrine coverage.

#### **2.4.2 Management systems.**

The traditional systems of pig rearing commonly practiced in rural communities like free range and tethering play a significant role in maintaining *T. solium* cysticercosis in humans and pig populations. This is because such systems of management allow pig's access to exposed faecal material, thereby enabling the continuity of the *T. solium* lifecycle (Carabin *et al.*, 2005; García *et al.*, 2007).

#### **2.4.3 Lack of knowledge.**

Lack of appropriate knowledge about *T. solium* cysticercosis and how its transmitted causes reluctance among the communities in ensuring proper hygiene and sanitation, confinement of pigs as well as other practices that limit the spread of this condition (García *et al.*, 2007).

Misperceptions by people in the disease endemic areas like “Tapeworm infections are only caused by eating of raw sweet potatoes and cassava” have made control of *T. solium* infection difficult. This is also coupled with misleading reports by media reporters who

have limited knowledge on transmission of *T. solium* cysticercosis alleging that “eating pork directly causes epilepsy”

Some reports indicate that people are aware about the infection but are ignorant of how it can be transmitted and controlled (Garcia *et al.*, 2010). Other findings however showed that prevalence in households with knowledge and those without had no difference (Rottbeck *et al.*, 2013). This could imply that occurrence of the infection in the community could be attributed to risk factors other than awareness of the condition.

Porcine cysticercosis has been shown to be prevalent in areas where inadequate or none inspection of pork is practiced (Maridadi, Lwelamira, & Simime, 2011) (Table 1). This is the case in most communities in Africa whereby pigs are slaughtered in ungazetted areas, especially backyards. The uninspected pork is then sold locally or transported to urban centres for marketing. This poses a serious risk to pork consumers especially when they eat undercooked pork, increasing the incidence of taeniosis and hence the possibility of porcine cysticercosis occurring becomes high ( Assana *et al.*, 2010; Lekule & Kyvsgaard, 2003).

## **2.5. Diagnosis of *T. solium* cysticercosis in humans and pigs**

Detection of occurrence of *T. solium* cysticercosis in human and pig populations in communities is important in forming the basis upon which control measures for the infection can be constituted ( Willingham *et al.*, 2010). In pigs, diagnosis of *T. solium* cysticercosis is done at ante mortem using tongue examination and immunological tests. It is also undertaken at post-mortem during meat inspection of predilection sites of cysts like the muscles, tongue, and heart (Nakaya, 2002; Ngowi *et al.*, 2004). Application of



ante mortem diagnostic tools in field conditions in developing countries is still limited, with lingual examination being the only used tool. This is because tools like serological tests for detection of antigens and antibodies for porcine cysticercosis are expensive, limiting their use to research studies. Such tests include ELISA, Lateral flow tests and PCR (Agudelo-Flórez & Palacio, 2009; Dorny *et al.*, 2003). Validating and making readily available under field conditions, the Dot blot test with a high sensitivity (86.4%) and specificity (93.2%) compared to lingual examination has been very helpful in detecting and hence control of porcine cysticercosis in Latin America (Schantz & Tsang, 2003; Sciutto *et al.*, 2003). There is ongoing work by Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) to validate a lateral flow blot test developed by Australian scientists for use in Africa. Though lingual examination is highly specific, detection of the condition at ante mortem where cysts have not manifested in the tongue is not possible (Flisser *et al.*, 2006). Antibody ELISA and immunoblot serodiagnostic tests are also available for detecting both porcine and human cysticercosis, though they only indicate that the subject being tested has had previous exposure to infection by the parasite, and not necessarily has a current viable infection (Dorny *et al.*, 2003). Researchers at the Centres for Disease Control and Prevention (CDC) in the USA have developed a serological test (immunoblot) specific for human infection with adult *T. solium*. The test is based on excretory/secretory antigens and is very sensitive and specific (CDC, 2010). This serological test has been suggested as a helpful tool in surveillance and control programs (Agudelo-Flórez & Palacio, 2009).

The use of antigen detection serological tests has been highly envisaged in recent studies of porcine cysticercosis. The challenge however is that no concurrent confirmatory test has been employed to reduce the biasness due to false positive results. In humans, specialized tools like Computerized Tomography (CT) scans, Magnetic Resonance Imaging (MRI), and X-rays are used to detect cysts in the brain. These are usually expensive, not widely available and are not appropriate for use in large population based studies (Foyaca-Sibat et al., 2009; OIE, 2008). Immunodiagnostic tests like immunoblot and ELISA are also used to detect *T. solium* specific antibodies and antigens in serum and Cerebral Spinal Fluid (CSF). These tests are helpful in demonstrating exposure and presence of active infection (Sciutto et al., 2003). Use of these tools is however debatable because correlation between a positive serology and neurological symptoms/lesions indicative of NCC in neuro-imaging techniques is poor to fair in most studies due to unpredictable clinical outcome of the infection and the variable immunological response of the human host to the infection. There is also lack of a gold standard for these tests (Sreedevi & Pradesh, 2013).

## **2.6. Control and eradication of *T. solium* cysticercosis**

*T. solium* cysticercosis has been declared eradicable but still remains an important neglected parasitic condition (Praet *et al.*, 2010). Control advances like vaccination of pigs, treatment of pigs and humans using anthelmintic, public education of people in Latin American countries like Mexico and Peru as well as in China have caused a temporary disruption of the transmission cycle and thereby lowering the disease prevalence (García *et al.*, 2007). This has not been the case in the African countries and South East Asian nations which have hardly taken such initiatives to combat the

condition. This is probably because priority has been given to other emerging pandemics that affect these impoverished nations. In order for this disease burden to be reduced, combining effective, affordable and sustainable control strategies should be done (Secka *et al.*, 2010). Prior to initiation of intervention measures, there is need to carry out baseline epidemiological surveys to ascertain the status of the condition in humans and pigs of the communities suspected to be affected by use of field applicable diagnostic tools (Willingham *et al.*, 2010). Screening of households to identify tapeworm carriers that act as transmission foci for porcine cysticercosis is also important in eliminating the source of infection. Control measures are aimed at limiting continuity of the life cycle of *T. solium* in the intermediate hosts (pigs and humans) and definitive hosts (Rottbeck *et al.*, 2013).

In pigs, the condition can be combated by encouraging full time confinement of pigs which prevents them from eating contaminated faecal materials. Although routine deworming with albendazole combined with ivermectin had earlier been suggested to minimize the occurrence of *T. solium*, recent studies have shown it is ineffective and have demonstrated that oxfendazole causes a significant reduction of the condition in pigs (Mkupasi *et al.*, 2013; Pondja *et al.*, 2012). Since pigs are indispensable intermediate hosts, effective vaccination using developed vaccines like S3PVAC (98% efficacy), TSOL18, TSOL45-1A (with up to 100% efficacy) is expected to reduce transmission and form a basis for eradication of the condition (CDC, 2010; Garcia *et al.*, 2010). Though vaccines have been developed and used in Latin American countries, feasibility of their production, affordability and effective usage in rural free ranging pigs in other disease

endemic countries remains a challenge (Lightowlers, 2003). Possible massive production and use of the TSOL18 vaccine is expected to start in Africa if the ongoing testing and validation process in the field by ASARECA is successfully completed.

The infection in human populations can directly be controlled by detection and massive chemotherapy against taeniosis and cysticercosis using drugs like oxfendazole, praziquantel and niclosamide (Pondja *et al.*, 2012). Treatment of humans against adult tapeworms reduces the occurrence of cysticercosis in pigs (Iburg *et al.*, 2012).

This measure is being undertaken in vulnerable groups like children, pregnant mothers and elderly people in developing countries. The effectiveness of this effort in control of the condition has however not been evaluated.

Sustainable control can also be achieved by stopping the sale and consumption of infected pork through ensuring that slaughtering of pigs is done in gazetted areas where meat inspection can be undertaken and infected meat is condemned. Except in Latin America and China, this is hardly implemented and slaughters are undertaken in backyards. In some countries that have gazetted pig slaughter places with meat inspectors, thorough inspection of pig carcasses is not guaranteed ( Assana *et al.*, 2010; Boa *et al.*, 2006).

In communities where inspection is not carried out, cooking pork at  $\geq 60^{\circ}\text{C}$  and freezing it at  $\leq 5^{\circ}\text{C}$  could help interrupt the life cycle (Mkupasi *et al.*, 2013). Reducing the risk of environmental contamination with the *T. solium* eggs by ensuring safe disposal of faeces plays an integral part in the control of the infection (Mwanjali *et al.*, 2013). Health

education through raising awareness among the people in communities that rear pigs and consume pork about the zoonotic implications and the transmission of the infection can be helpful in reducing the incidence of the infection<sup>40</sup>. The success of a porcine cysticercosis control campaign can be evaluated by carrying out epidemiological surveys in pigs in the affected area. A lowered seroprevalence of *T. solium* in pigs is indicative of a minimized incidence in humans ( Ngowi *et al.*, 2008). The challenge in most of these developing countries however is that very few epidemiological surveys on PC in pigs exist, with no published findings available on the condition in humans. The studies already undertaken have used small sample sizes, non-confirmatory screening techniques making it difficult to generate reliable findings to draw conclusive remarks on the extent of *T. solium* cysticercosis in pig and human populations (Table 2).A summary of the status of *T. solium* cysticercosis in Latin America, South-East Asia, and Africa is presented in Tables 2.4, 2.5, 2.6, 2.7.

**Table 2.4:** Economic impacts of *T. solium* cysticercosis in Latin America, South-East Asia, and Africa

Latin America	South-East Asia	Africa
<ul style="list-style-type: none"> <li>•In <i>Mexico</i>, estimated US \$164 Million (Murrell et al., 2005) and 25,341 DALYS lost due to clinical neurocysticercosis(Willingham &amp; Engels, 2006).</li> <li>•In <i>Peru</i> up to \$966 is estimated to be spent on treatment of a neurocysticercosis patient for 2 years(Flisser et al., 2003).</li> </ul>	<ul style="list-style-type: none"> <li>•In <i>China</i> pig production loss of US \$121 Million occurs annually and 3-6 Million people in the endemic areas are affected.</li> <li>•In the <i>Indian</i> sub-region, 4.2% of the economic worth of pigs is lost due to condemnation of affected carcasses ( Willingham et al., 2010) .</li> </ul>	<ul style="list-style-type: none"> <li>• In <i>Cameroon</i> pig production losses of €478,844 and €45,838.4 of DALYS (Praet et al., 2009).</li> <li>• In <i>South Africa</i>, US \$5Million production losses (Foyaca-Sibat et al., 2009).</li> </ul>

**Table 2.5:** Risk factors of *T. solium* cysticercosis in Latin America, South-East Asia, and Africa

Latin America	South-East Asia	Africa
<ul style="list-style-type: none"> <li>• Free roaming of pigs, unprotected water sources and open air-defecation.</li> <li>• Tapeworm carriers, a possible source of infection in household clustering of this condition (Morales &amp; Martínez, 2010)</li> </ul>	<ul style="list-style-type: none"> <li>• Improper sanitation</li> <li>• Poor pig management practices and lack of pig meat inspection.</li> <li>• Sociocultural practices of the human populations whereby some communities have preference for pork to other meat products (Conlan <i>et al.</i>, 2009).</li> <li>• Alternative hosts for <i>T. solium</i> cysticercosis such as dogs where they are a delicacy (Rajshekhar <i>et al.</i>, 2003).</li> </ul>	<ul style="list-style-type: none"> <li>• Poor hygiene and sanitation practices in humans, rearing pigs by free-range and tethering.</li> <li>• Lack of awareness about the disease and its transmission, non-inspection of pigs before or following slaughter, and age of pigs have been described to occur (Assana <i>et al.</i>, 2010; Krecek <i>et al.</i>, 2012; Morales &amp; Martínez, 2010; Ngowi <i>et al.</i>, 2010)</li> </ul>

**Table 2.6:** Diagnosis of *T. solium* cysticercosis in Latin America, South-East Asia, and Africa

Latin America	South-East Asia	Africa

<ul style="list-style-type: none"> <li>• Tongue examination</li> <li>• Meat inspection</li> <li>• Serology in pigs.</li> <li>• Neuroimaging and used in humans (Carabin <i>et al.</i>, 2005) .</li> </ul>	<ul style="list-style-type: none"> <li>• Meat Inspection in pigs</li> <li>• Serological tests</li> <li>• Neuro-imaging tests to confirm presence of the condition in humans and monitor progress of treatment in a few patients who can afford (Singh <i>et al.</i>, 2013; Sreedevi <i>et al.</i>, 2012) .</li> </ul>	<ul style="list-style-type: none"> <li>• Tongue examination is rarely carried out by traders during buying of pigs.</li> <li>• Post-mortem meat inspection of predilection sites of cysts like the muscles, tongue, and heart is also practiced on a non-routine basis in few formal slaughter places (Assana <i>et al.</i>, 2010, 2010b; Foyaca-Sibat <i>et al.</i>, 2009; Ramahefarisoa <i>et al.</i> , 2010)</li> <li>• The use of serological tests like ELISA, Lateral flow tests</li> <li>• PCR for detection of antigens and antibodies for <i>T.solium</i> cysticercosis are expensive and have been limited to research studies.</li> <li>• Neuroimaging and serology applied in humans during research studies (Foyaca-Sibat <i>et al.</i>, 2009).</li> </ul>
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**Table 2.7:** Advances in control of *T. solium* cysticercosis in Latin America, South-East Asia, and Africa

Latin America	South-East Asia	Africa
<ul style="list-style-type: none"> <li>• Improved pig rearing practices</li> <li>• Raising community awareness on the disease</li> <li>• Massive chemotherapy against taeniasis and <i>T. solium</i> cysticercosis have been employed (Hector H García <i>et al.</i>, 2007).</li> <li>• Development and application of vaccines such as TSOL18, TSOL45-1A and S3PVAC to pig herds has been shown to be useful (Flisser <i>et al.</i>, 2006; Sciotto <i>et al.</i>, 2003). It is presumed that this has temporarily interrupted the transmission cycle of the condition.</li> </ul>	<ul style="list-style-type: none"> <li>• With the exception of China, not much progress has been made to reduce on the disease burden. Most affected countries are relying on meat inspection during post-mortem to hinder the transmission cycle by condemnation and disposal of infected pork (Conlan <i>et al.</i>, 2009).</li> <li>• In China, surveillance and intervention measures such as mass-screening and treatment of taeniosis carriers, treatment of <i>T. solium</i> cysticercosis patients and pigs, meat inspection and raising public awareness are ongoing in the endemic areas (Willingham <i>et al.</i>, 2010).</li> </ul>	<ul style="list-style-type: none"> <li>• Meat inspection in a few gazetted slaughter places.</li> </ul>

**Table 2.8:** Limitations of *T. solium* cysticercosis in Latin America, South-East Asia, and Africa

Latin America	South-East Asia	Africa
<ul style="list-style-type: none"> <li>• No reliable gold standard test for diagnosis of NCC.</li> <li>• No published reports on any extensive studies in recent years to estimate the level of such interruptions</li> </ul>	<ul style="list-style-type: none"> <li>• No large scale studies except in China and India. Limited interventions. No studies in humans.</li> </ul>	<ul style="list-style-type: none"> <li>• No large scale studies. Limited interventions. No studies in humans.</li> </ul>



## 2.7 Conclusion

Although the International Task Force for Disease Eradication (ITFDE) in 1993 declared *T. solium* a potentially eradicable parasite, no intervention programs have successfully been implemented at any national level to stump out this condition<sup>14</sup>. In most African and South .East Asian countries, few efforts have been envisaged in attempt to control or eliminate *T. solium* cysticercosis. The condition has remained a neglected infection with priority being given to emerging diseases with direct and immediate high mortality and morbidity effects in both human and livestock populations. The pig, an intermediate host playing a pivotal role in maintaining *T. solium* infection is not a priority animal in the developing countries' plan for development of the livestock industry. This implies that no financial and human resources have purposely been set aside by the governments to promote pig health and development of the pig industry despite the role it plays in improvement of livelihoods of the rural poor.

## **CHAPTER THREE**

### **DISTRIBUTION OF PORK OUTLETS AND EXISTING POTENTIAL FOR TRANSMISSION OF FOOD-BORNE INFECTIONS IN KAMPALA DISTRICT, UGANDA**

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#### **Abstract**

A study was conducted in Kampala district, Uganda to map the distribution of pork retail outlets as well as assess their role in food borne disease transmission. This was the first study to map pork retail outlets and their hygiene in Kampala, a city considered to be a major destination for pigs from different parts of the country.

We identified pork outlets by traversing major routes and by asking each outlet encountered about the location of others. Pork outlets were geo-referenced and mapped.

Using a structured questionnaire, practices associated with hygiene related to infrastructure (e.g. water, refrigeration), workers (e.g. cleanliness, uniforms), and equipment (e.g. presence, condition) were assessed. Sources of pork were assessed to determine whether pork had undergone inspection, as were socio economic determinants of hygiene outcomes (e.g. gender and years of business operation) and risk factors for foodborne disease (consumption of salads and alcohol)

There were 158 pork outlets in the five divisions of Kampala with the highest number (42) in Makindye division. Overall, 68% of the pork eaten in Kampala is from places where slaughtering was not authorized (un-gazetted) and meat inspection not carried out. The overall average hygiene score was 61% with considerable variation between districts. Worker hygiene score was highest (average 71%), followed by infrastructure (68.2%) and equipment (47.3%). There was a significant relation between good hygiene and the presence of a public health certificate (present only in 42% of the outlets).

Although some aspects of hygiene in pork retail outlets are good, there is also room for improvement. The lack of meat inspection for most pork presents a risk. Having a public health certificate is an important predictor of good practices.

**Keywords:** Pork, contamination, hygiene practices, Kampala.

### **3.1 Introduction**

Pork has in recent years become an important meat in Uganda, second only to beef in the amount consumed. With a population of over three million, the country's pig industry has

experienced tremendous growth in recent decades (The Republic of Uganda MAAIF, 2011). Although consumption per capita is still only 3.4kg/person/year, pork is a popular source of protein for both rural and urban population (FAOSTAT, 2014). Kampala, the capital of Uganda is the main marketing hub for pork from the leading pig producing communities in the country (Ouma *et al.*, 2014). A considerable proportion of pigs slaughtered in the district are kept in the peri-urban areas (The Republic of Uganda MAAIF, 2011).

Most of the pork produced in the country is distributed and sold through informal market channels where food safety practices such as inspection of the pork and the hygiene of sale premises are perceived to be uncommon (Ouma *et al.*, 2014). There is only one gazetted slaughter place for pigs in Kampala called “Wambizzi Cooperative Society Ltd.”; but most pigs that reach Kampala, are slaughtered in backyards or vacant land near pork outlets (Daily Monitor, 2015). Studies done in other developing countries indicate that slaughter of pigs in un-gazetted places makes meat inspection difficult to implement, thereby increasing risks of pork-borne infections (Joshi *et al.*, 2003; Krecek *et al.*, 2012; Maridadi, Lwelamira, & Simime, 2011).

Pork becomes unsafe for human consumption when the pig slaughtered was infected with zoonotic pathogens or if the meat is contaminated with pathogens during the handling process (Haileselassie, Taddele, & Adhana, 2012; Joshi *et al.*, 2003). Handlers of pork are at risk from pork-borne disease as are consumers (Eshitera *et al.*, 2012; Mwanjali *et al.*, 2013), (Aiello & Larson, 2002). In developing countries, conditions such as salmonellosis, *Escherichia coli* gastroenteritis, taeniasis, amoebiosis, shigellosis, cholera,

toxoplasmosis, rotavirus infection and typhoid are associated with contaminated food and can cause severe effects (Bogere & Baluka, 2014; Ifeadike *et al.*, 2014). Contamination has been associated with un-gazetted slaughter areas but licensed slaughter houses may also be problematic (Jumaa, 2005). Food handlers can be a source of contamination (Nyarango *et al.*, 2008).

The objective of this work was to map the location of pork outlets in Kampala and to assess hygienic practices, their socio-economic determinants and risk factors for pork borne disease. The work was part of CGIAR research that will allow emerging pig farmers to improve their productivity and livelihoods, while increasing the supply of safe food to rural communities and urban centres.

## **3.2 Materials and methods**

### **3.2.1. Study area.**

Kampala district is the capital city of Uganda, bordered by Wakiso District to the south, west and north and by Mukono District in the east (coordinates 00°19'N, 32°35'E) at an elevation of 1,200 m (3,900 ft) (Figure 1). According to the Uganda Bureau of Statistics the population of people in Kampala was estimated to be 1,659,600 in 2011. The district is located in the central region of the country, making it a market hub for pigs reared in the rural communities of the different parts of the country. Although on a small scale, pig rearing is done in backyards in some peri-urban areas with an estimated population of 38,306 (The Republic of Uganda MAAIF, 2011). Kampala has five divisions: Kawempe,

Rubaga, Makindye, Nakawa and Kampala central administrative division. All divisions were part of the study.

### **3.2.2. Study design.**

A survey was carried out in Kampala district from May to June 2012, to map the pork retail outlets and assess hygiene practices along the market chain from the pig slaughter places to the pork retail outlets. Pork retail outlets in this study constituted two categories: pork eateries where only cooked pork was sold and butcheries/eateries where both raw and cooked pork was sold.

After identifying the first pork outlet and obtaining data, directions to the location of the next outlets were obtained from the respondent. Global Positioning System (GPS) points of the pork outlets were taken during the survey and used to generate a map using Esri's ArcGis software (version 10.1). An observation checklist was used to assess the practices of a backyard pig slaughter place in Church zone, Kamwokya, and the gazetted Wambizzi abattoir in Rugaba. A structured questionnaire was used to assess hygiene practices of the pork retail outlets. Prior to conducting the study, the tools were pretested in two pork outlets in Namasuba-Kikajjo zone, Wakiso district. The questionnaire was administered to the respondents by two veterinary officers fluent in Luganda, the commonly used local language, and English. Direct observations were also carried out by interviewers using a structured checklist.

### **Statistical analysis**

Hygienic practices were divided into three categories: infrastructure (n=9 variables); equipment presence and condition (n=8 variables); and, worker hygiene (n=5 variables). Hygienic responses were summed into an overall hygiene score, which was also standardized to a percentage score. Robust linear regression, accounting for clustering of data within districts, was used to assess the relation between the hygiene score and predictors (gender of owner, years in operation, type of establishment, and presence of a medical certificate). Data were analysed with Stata 11.

### **3.3 Ethical considerations.**

The study was approved by the Research and Ethics Committee of the College of Veterinary Medicine Animal Resources and Biosecurity of Makerere University (Reference No: VAB/REC/13/104). Prior to questionnaire administration, verbal consent was obtained from the respondent after clear explanation of the purpose of the study.

## **3.4 Results**

### **3.4.1. Location of pork retail outlets.**

In all, 179 retail outlets were identified in Kampala district during the study. Twenty-one of these were not mapped because they were closed (n=18) or owners did not consent to the study (n=3). Of the 158 outlets mapped, Makindye division had the highest number of outlets (42) and Kampala Central had the least (6). The locations were displayed in the map illustrated in Figure 3.1. Of the 158 outlets identified, only 17 (10.7%) were pork

eateries and the rest were butcheries/eateries. All the pork eateries were managed by men while 12 of the 141 butcheries/eateries (8.5%) were managed by females (Table 3.1). All outlets except one (99.3%) sold alcohol and 82% of outlets sold salads as accompaniments to the cooked pork.



**Figure 3.1:** Distribution of pork eateries/retail outlets in Kampala district at the time of study.



**Table 3.1:** A summary of respondents by gender in pork outlets in five divisions of Kampala district.

Respodent gender	Kampala Central , n(%)	Kawempe, n(%)	Makindye, n(%)	Nakawa, n(%)	Rubaga, n(%)	Total, n
Male	5 (3.4)	36(24.6)	39(26.7)	29(19.9)	37(25.3)	146
Female	1 (8.3)	3 (25.0)	2 (16.7)	3 (25.0)	3 (25.0)	12
Total	6	39	41	32	40	158

### 3.4.2. Hygiene practices associated with pig slaughter places and pork marketing.

Practices that affect slaughter hygiene were assessed in an un-gazetted slaughter place (Church zone Lufula, Kamwokya) and a gazetted slaughter place (Wambizi abattoir).

Table 3.2 depicts the two scenarios.

**Table 3.2:** A comparison of an un-gazetted pig slaughter place (Church zone Lufula, Kamokya) and a gazetted pig slaughter place (Wambizi abattoir) in Kampala, Uganda.

Variable	Church zone Lufula	Wambizzi abattoir
Location	On the outskirts of Kamokya town centre; in swampy ground with a dirty surrounding and open drainage channels.	In an industrial setting with a fairly clean surrounding.
Structures present	Holding pens and open ground. Pigs slaughtered and carcass scalded and cleaned on grass/soil.	Holding pens, stunning area, area for scalding and cleaning carcasses, hanging areas for inspection, weighing and sale area. Offices for inspectors and management.
Number of pigs slaughtered per day	5-10 pigs.	50-70 pigs.
When are pigs slaughtered	Usually done before 7.00am. However more can be slaughtered in the day based on need.	Done early before 7.00am.

Clients served	Most pork outlets in the locality.	Whole Kampala area and formal processors.
Marketing and transportation	Usually done by hand lifting to nearby outlets, packed in sacks and ridden on bicycles or motorcycles.	Can be sold locally, transported to distant destinations using pick-up cars and motor cycles.
Meat inspection	Not done.	Ante-mortem and post-mortem checks done by a full-time meat inspector.

### 3.4.3. Hygienic practices at pork outlets.

The average overall hygiene score was 61.3% with a range of 13.6-100%. Worker hygiene score was highest (average 71%), followed by infrastructure (68.2%) and equipment (47.3%). There were differences between divisions with butchers in Kampala Central, Nakawa and Kawempe scoring 78%, 78% and 72% respectively, Makindye scoring 57% and Rubaga just 38%. The levels of compliance with different aspects of good hygienic practices are given in table 3.3.

**Table 3.3:** Compliance with good hygienic practices in pork retail outlets in Kampala, Uganda

Infrastructure	Complying (%)	Worker hygiene	Complying (%)	Equipment	Complying (%)
Protected water source	99	Wounds covered	93	Equipment clean	73
Use warm water and soap	79	Nails kept short	91	Equipment dent free	73
Outlet with adequate light	74	No food or drink	59	Equipment in good repair	68
Fridge present	65	Beard & hair trimmed	58	Clean wooden stump	60
Butchery/eatery clean	63	Clean overall	54	Pork always hung	44
Outlet in good state of repair	61			Covered rubbish bin	37
Cleanable walls	61			Equipment not rusty	15

Platform for pork display	57
Protection from flies	55

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#### 3.4.4. Determinants of hygienic practices.

After controlling for the putative socio-economic determinants of hygienic practices, the only significant was the presence of a medical certificate, which had a large, significant and positive effect on the hygiene score (Table 3.4).

**Table 3.4:** Robust linear regression predicting hygiene score of retail outlets in Uganda

Variable	Coefficient	P
Years in business	-0.03	0.495
Male owner	-0.7	0.779
Public health certificate	4.19	0.018
Source from Wambizzi	-2.11	0.175
Butchery	-1.41	0.195

### 3.5 Discussion

Although the study was intended to exhaustively map all outlets, it is probable that some were missed since the exercise was conducted along roads and in trading centres, which were identified using the district administrative map.

This study confirms increasing demand of pork with a considerable number of outlets established in all Kampala districts. The demand could be driven by the improving

incomes, growing social clusters and less interference of religious sentiments that made pork less popular in the past (FAO, 2013; Ouma *et al.*, 2014). Demand is also thought to be influenced by alcohol consumption and a strong association between alcohol sale and pork was found in this study. Ownership of pork outlets was dominated by men. This was also noted in a value chain assessment in Masaka, Mukono and Kamuli district whereby except at the production level, women's involvement in the pig value chain was minimal (Ouma *et al.*, 2014). There was a tendency for women operated outlets to have better hygiene but this result was not significant possibly due to the small number of women.

The study demonstrated that most pork consumed in Kampala was un-inspected and could pose a risk of meat borne infections to consumers. Similar studies in Dar es Salaam city in Tanzania, and East Cape Province South Africa also disclosed that poor hygiene of most slaughter places and lack of inspection posed a serious public health challenge (Krecek *et al.*, 2012; Ngowi *et al.*, 2004). The role of meat inspection in eliminating infections such as *T. solium* cysticercosis and echinococcosis has been described in various studies (Boa *et al.*, 2006; Joshi *et al.*, 2003; Ngowi *et al.*, 2004; Sakai *et al.*, 2001). Just like in other developing countries where such a challenge occurs, lack of meat inspection has been due to failure to implement the Public Health (PH) legislations that enhance meat safety (Joshi *et al.*, 2003).

Unlike in a study in Kenya where only 40% practiced hand hygiene, almost all outlets used clean water and soap (Ghimire, Dhakal, & Pandeya, 2013). Keeping nails short which was a common practice could have helped reduce load of micro-organisms that inhabit the hands and makes hand washing more effective as reported elsewhere (Jumaa,

2005). A considerable number of pork handlers worked without protective clothing. This was in agreement with reports in Ethiopia and India (Ghimire *et al.*, 2013; Haileselassie *et al.*, 2012). Poor disposal of waste was a key challenge in the study and it is agreement with observations elsewhere (Ifeadike *et al.*, 2014; Lawan *et al.*, 2013). It could be promoting transmission of pathogens from wastes to pork by flies especially in outlets where pork was exposed (Aiello & Larson, 2002). Many pork sellers admitted not to have been medically examined. It was likely that carriers of parasites transmitted through faeco-oral route could be among those handling pork at retail outlets (Flisser *et al.*, 2006; Sciutto *et al.*, 1995).

Most of the pork outlets were operated without a PH certificate. According to the PH act, in order to acquire a medical certificate, the premises where the outlet operates has to be assessed by health inspectors and a laboratory report indicating that the pork sellers (handlers) have undergone a medical check-up and are free of parasitic conditions that can contaminate food (including tapeworms) (The Republic of Uganda, 1964). Presence of a PH certificate was significantly associated with better hygiene practices; however, it is difficult to establish a causal link as the relation may have been due to a confounding factor (e.g. location). Similar observations were made in Ethiopia, Nigeria and Nepal where poor implementation of PH health regulations on meat hygiene encouraged poor hygiene in outlets (Edia-asuke *et al.*, 2014; Haileselassie *et al.*, 2012; Joshi *et al.*, 2003). The PH act in Uganda sets guidelines for establishment and operation of slaughter places and retail outlets. Likewise, the meat handlers are meant to undergo medical examination to be allowed to handle meat (The Republic of Uganda, 1964).

### **3.6 Conclusion and recommendations**

Consumption of pork in Kampala is high in the district. The district lacks gazetted abattoirs for pigs meaning there is a lack of meat inspection and monitoring of hygiene practices is difficult. Hygiene practices in retail butcheries/eateries are still wanting, but the fact that a minority of outlets of excellent hygienic practices exist suggests improvements are feasible. Implementation of the PH regulations was useful in promoting practices that led to good hygiene.

There is need for Kampala City Council Authority (KCCA) to set up low cost slaughter facilities in each of the five divisions. Traders in each division could be organized in groups and given training on good meat hygiene practices. The Ministry of Agriculture, Animal Industry and Fisheries and KCCA should ensure the PH regulations on meat hygiene are implemented. Studies need to be conducted to assess contamination in pork sold in the retail outlets.

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## CHAPTER FOUR

### SEROPREVALENCE OF *TAENIA SOLIUM* CYSTICERCOSIS IN PIGS IN MASAKA, MUKONO AND KAMULI DISTRICTS OF UGANDA

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#### Abstract

The pork tapeworm, *Taenia solium*, is endemic in Uganda although the prevalence has not been determined in all areas of the country. A cross-sectional study, to determine the sero-prevalence of the parasite in pigs kept under rural and urban production systems, was carried out in three Ugandan districts, Masaka, Mukono and Kamuli. Serum samples from 1185 pigs were tested for the presence of *T. solium* cysticercosis antigen using the HP10 antigen-ELISA (Ag-ELISA) and the ApDia Ag-ELISA assays. Using parallel interpretation of the two tests showed lower levels of observed prevalence of *T. solium* in

rural production systems (10.8%) compared to urban (17.1%). Additionally, Maximum Likelihood Estimation for evaluating assays in the absence of a gold standard, using TAGS on the R platform, estimated the true sero-prevalence to be lower in rural production systems, 0.0% [0.0-3.2%; 95% confidence interval (CI)] than in urban production systems, 12.3% (4.2-77.5% CI). When the sensitivity/specificity (Se/Sp) of the assays were estimated, assuming conditional independence of the tests, HP10 Ag-ELISA was more sensitive and specific [(Se=53.9%; 10.1-100% CI), (Sp=97.0%; 95.9-100% CI)] than the ApDia assay [(Se=20.2%; 1.5-47.7% CI), (Sp=92.2%; 90.5-93.9% CI)]. Subject to parasitological verification, these results indicate there may be a need to implement appropriate control measures for *T. solium* in the study areas.

**Key words:** Pig, sero-prevalence, *Taenia solium*, cysticercosis, rural and urban production systems, Uganda

## 4.1 Introduction

*Taenia solium* neurocysticercosis is considered a serious neglected, public health concern particularly in areas with poor standards of sanitation, public health and inappropriate animal husbandry practices (Secka *et al.*, 2010; WHO, 2013). The pig is the primary intermediate host (porcine cysticercosis) and humans are the definitive host (taeniosis) (Soulsby, 1982). Dogs can also act as intermediate hosts (Ito *et al.*, 2002), as can humans leading to human cysticercosis / neurocysticercosis. The latter being the leading cause of late onset epilepsy in pig-keeping communities in the developing countries(WHO, 2014).



In recent years the pig population in Uganda has grown (>15%), with an estimated total population of over 3.2 million pigs in 2008 (MAAIF, 2011). Factors including; their high fecundity and conversion rate, their early maturity, short generation interval and minimal space requirements, have made pigs an important source of livelihood for over 1.1 million resource-poor farmers in the rural and peri-urban communities as well as some urban centers in Uganda (UBOS, 2009; Ouma *et al.*, 2014). This growth has resulted from increased demand for pork and pork products by consumers, with the consumption *per capita* of pork in Uganda being estimated at 3.4kg/person/year (FAOSTAT, 2014). Various studies have associated growth in pig production and pork consumption in developing countries with increasing prevalence of *T. solium* cysticercosis, especially in pigs under poor management (Assana *et al.*, 2010; García *et al.*, 2003; Mwape *et al.*, 2012; Praet *et al.*, 2010). The parasite is known to be endemic in areas of Uganda (Nsadha *et al.*, 2014; Waiswa *et al.*, 2009).

In urban production systems in Uganda, pigs are commonly kept in corrals whereas pigs in rural areas are kept under extensive management systems (Dione, *et al.*, 2014). The later system may promote parasite transmission (Eshitera *et al.*, 2012; Pondja *et al.*, 2010).

The main objective of this study was to determine and compare the seroprevalence of *T. solium* cysticercosis in the rural and urban smallholder pig production systems of three districts in Uganda, where there was little previous knowledge regarding prevalence of the parasite.

The study has also demonstrated the use of the Maximum Likelihood Estimation (MLE) method to estimate prevalence, sensitivity and specificity in the absence a gold standard diagnostic test (Dohoo, Martin and Stryhn, 2009).

## 4.2 Materials and methods

### 4.2.1. Site selection.

A cross-sectional survey was conducted from April to August 2013 in Masaka, Mukono and Kamuli districts of Uganda by the Smallholder Pig Value Chain Development (SPVCD) project and its partners (Ouma, *et al.*, 2014). Districts were selected through geographical targeting and through stakeholder consultation. For the purposes of the study reported here, 22/35 of the villages identified in that study were selected across the three districts (Table 4.1). The number and choice of villages was based on financial resources available and also to avoid other activities taking place in the same villages, to minimise farmer fatigue.

**Table 4.1:** Pig population and sample sizes in the study districts

Value-chain domain	District	Village	Number of households	Number of pigs (N)	Number of pigs sampled (n)
U-U	Masaka	Kyabakuza-B	74	357	36
		Kijjabwemi	90	265	45
		Senyange A	69	219	51
R-U		Kisoso	88	351	47

		Butego	63	217	30
		Kanoni-Bukunda	131	385	49
		Kyamuyimbwa-	102	312	39
		Kikalala			
R-R		Ssenya	76	240	37
		Lukindu	54	226	41
Sub-Total			971	3258	375
R-R	Kamuli	Butabala	84	191	40
		Ntansi	136	314	111
		Kantu	120	320	113
		Bukyonza	60	86	29
		Baluboinewa	62	113	46
		Isingo B	100	213	69
Sub-Total			636	1336	408
U-U	Mukono	Jogo	103	684	68
		Kitete	63	379	58
R-U		Kyoga	80	153	56
		Dundu	69	224	61
R-R		Kazo/Kalagala	85	272	59
		Bugoye/Kabira	91	261	51
		Nsanja/Gonve	89	266	49
Sub-Total			893	4232	402

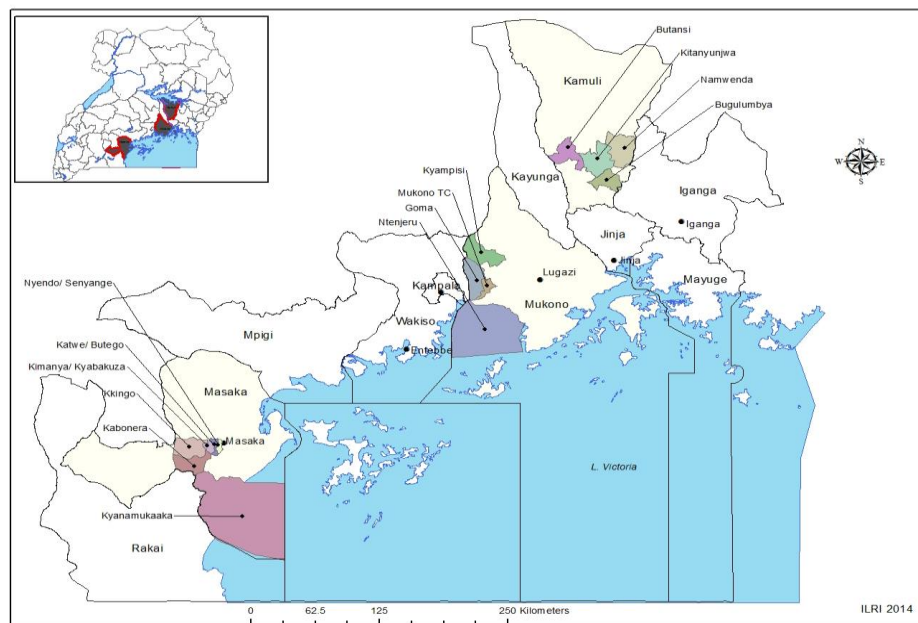
Total	2503	8826	1185
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R-R: Rural production for rural consumption; R-U: Rural production for urban consumption;

U-U: Urban production for urban consumption

In order that we might compare rural and urban production systems, value chain domains that were identified by Ouma *et al.* (2014) as rural production for rural consumption; and rural production for urban consumption were classified as “rural” and urban/peri-urban production for urban consumption was classified as “urban” production. Note that Kamuli district was not considered to include any form of urban production system.

Figure 4.1 shows the districts and sub-counties where pigs were sampled.



**Figure 4.1:** A map of Uganda showing Masaka, Mukono and Kamuli districts and the selected sub-countie

#### **4.2.2. Sample size determination.**

The original sample size was calculated to estimate district-level prevalence of undefined diseases, i.e. not specifically for this study, and assuming an infinite population (no recent census data) using the formula adopted from Thrusfield (2007) as follows:  $n = [Z^2P(1-P)]/d^2$  Where:  $n$  is the required sample size;  $Z$  is the multiplier from a standard normal distribution (1.96) at a probability level of 0.05;  $P$  is the estimated prevalence which is most conservatively estimated to be 50% considering that there is no reliable prevalence data for *T. solium* cysticercosis in pigs in two of the districts under study (Mukono and Masaka) and  $d$  is the desired precision for the estimate ( $\pm 5\%$ ). A sample size of 384 pigs was required for the study in each district. However, to increase precision, a sample size of 400 pigs in each district was considered; in the field, a total of 375, 408, and 402 pigs were sampled in Masaka, Kamuli and Mukono, respectively. The actual number of pigs sampled in Masaka was lower than the required sample size because of the harsh working conditions experienced due to heavy rain. Post-hoc power calculations for this study, using Stata 10.0 (Stata Corp, LP USA) indicated a power of 75% to show significantly different prevalence levels between rural and urban production systems at the 5% level of significance, for the study observed prevalence of 10.8% (100/927) in rural and 17.1% (44/258) in urban systems, implying that the selected sample size was reasonable. However, this power has not been adjusted for potential intra-cluster (village) correlation.

#### **4.2.3. Household and pig selection.**

A list of all pig keeping households was generated by local partners in each village. The study households were then randomly selected using computer-generated random

numbers. Apparently healthy pigs over three months of age were selected. Pregnant sows or sows with litters under two months old were excluded. One pig fulfilling the inclusion criteria was randomly selected for blood collection.

#### **4.2.4. Collection of blood samples.**

Pigs were restrained using a catcher and bled from the anterior vena cava using BDVacutainer® needles (gauge 19) and BDVacutainer® plain tubes (10ml). The blood samples were kept standing in an ice box at +4°C to ensure no hemolysis occurred while in the field. At the laboratory, blood was centrifuged to separate serum from blood clot. Serum was harvested into barcoded 2ml vials that were stored at -20°C until processing.

#### **4.2.5. Serological analysis.**

Serological analysis for *T. solium* cysticercosis antigen was carried out at the International Livestock Research Institute (ILRI) laboratories in Nairobi, Kenya employing the HP10Ag-ELISA (Harrison et al., 1989) with some modifications to that described by Krecek et al., 2008, 2011 and, the commercially available B158C11A10/B60H8A4 Ag-ELISA (apDIA Cysticercosis) following the manufacturers protocol (ApDia n.v, 2004). The assays were conducted on the same serum samples, beginning with the HP10 Ag-ELISA and one month later by the ApDia assay.

These tests detect the secretory and excretory products of viable cysticerci (Alcobedes *et al.*, 2010). Although some authors reported having detected antigens in a pig with only one viable cyst, assay efficiency is positively related to cyst burden (Rodriguez-Hidalgo *et al.*, 2006).

The cut-off values for the two assays differed, with that for the Ap-Dia assay ( $3.5 \times \text{mean ratio} > 1.3$ ) being much more stringent than the HP10 Ag-ELISA [ $> (\text{negative control mean} + 3 \text{ standard deviation})$ ]

The different cut-off calculations, potentially could have had an effect, on the overall results and therefore a comparison was made of the of seroprevalence values of HP10 and ApDia assays applying both cut-off determinations to both sets of assay results. This may have been the underlying cause of obtaining different results when the two ELISA tests are performed on the same samples (Krecek *et al.*, 2008, 2011).

#### **4.2.6. Statistical analyses.**

A McNemar chi-square test for the correlation between the proportion of positive results for HP10 and ApDia assays was conducted and a simple comparison of number of positive tests used to hypothesize as to the level of independence of the tests. The two assays are not ‘gold standard’, as they do not have perfect specificity (i.e.  $Sp = 1$ ) or sensitivity (i.e.  $Se = 1$ ) (Enøe *et al.*, 2000). In the absence of this gold standard test, Maximum Likelihood Estimation (MLE)(Dohoo, Martin and Stryhn, 2009), which can be used if at least two populations (rural and urban) have differing prevalence, was carried out using TAGS program on the R platform (Pouillot *et al.*, 2002) to estimate and compare the seroprevalence of *T. solium* cysticercosis in pigs in the rural and urban production systems as well as the sensitivity and specificity of the assays, with bootstrapped 95% confidence intervals (1000 samples), assuming conditional independence for the tests.

### 4.3 Ethical Considerations

Ethical approval was granted by the Research and Ethics Committee of the College of Veterinary Medicine, Animal Resources and Biosciences of Makerere University (Reference No: VAB/REC/13/104) and by the Ugandan National Council for Science and Technology (UNCST) (Reference Number: HS1477). All farmers signed a consent form to participate in the study and to allow their pigs to be bled.

### 4.4 Results

The number of positive and negative results of HP10 and ApDia Ag-ELISA assays and hence the observed (apparent) prevalence of *T. solium* cysticercosis for each assay in the two production systems, rural and urban, and overall is shown in Table 4.2.

**Table 4.2:** Observed prevalence of the infection in rural and urban production systems for each test, HP10 Ag-ELISA and ApDia Ag-ELISA, separately.

Ag-ELISA result (+/-)		Production system		
HP10	ApDia	Rural	Urban	Overall
-	-	827	214	1041
+	-	72	20	92
-	+	28	20	48
+	+	0	4	4
Total samples		927	258	1185
Observed prevalence (HP10)		72 / 927 = 7.8%	24 / 258 = 9.3%	96 / 1185 = 8.1%
Observed prevalence (B158/B60)		28 / 927 = 3.0%	24 / 258 = 9.3%	52 / 1185 = 4.4%



The observed (apparent) prevalence in the rural production system is lower than in urban system for both tests. However, the level of agreement in the tests appears to be low (Table 4.3) with 96/1185 (8.1%) positive by HP10 Ag-ELISA but only 52/1185 (4.4%) positive by ApDia Ag-ELISA and the significant McNemar chi-square test result confirms this ( $\chi^2=13.83$ ,  $p<0.001$ ).

**Table 4.3:** Contingency table showing level of agreement in observed (apparent) prevalence between the HP10 Ag-ELISA and ApDia Ag-ELISA results.

ApDia	HP10		
	Positive (+)	Negative (-)	Overall
Positive (+)	4	48	52
Negative (-)	92	1041	1133
Overall	96	1089	1185

Additionally, the number of samples testing positive in both tests (=4) equals the expected number of positives if the tests are independent ( $8.1\% \times 4.4\% \times 1185 = 4.2$ ) and while recognizing this evidence is not overwhelming, because of low numbers of positive observations, for the remainder of the analysis the two tests are considered to be conditionally independent. This conditional independence implied that we had to interpret the two tests in parallel, i.e. a sample was considered ‘positive’ if positive by either the ApDia or HP10 ELISA test.

Table 4.4 summarizes the apparent prevalence, interpreting the two tests in parallel (ie a sample was considered positive if positive in either or both of the two assays), of the infection in districts with rural and urban production systems. Similar to individual test interpretation (Table 4.2) the apparent prevalence in rural areas (10.8%) is lower than in

urban areas (17.1%) although all estimates are higher overall because of the change in interpretation.

**Table 4.4:** Apparent prevalence of the infection in rural and urban production systems, by district – interpreting the two tests (ApDia, HP10) in parallel

District	Production System (positive / total samples)		
	Rural	Urban	Overall
Kamuli	(55/408) 13.5%	---	(55/408) 13.5%
Masaka	(20/243) 8.2%	(24/132) 18.2%	(44/375) 11.7%
Mukono	(25/276) 9.1%	(20/126) 15.9%	(45/402) 11.2%
Overall	(100/927) 10.8%	(44/258) 17.1%	(144/1185) 12.2%

The breakdown by district is presented here to recognize that Kamuli district samples came only from the rural production system and represent partial confounding of production system with district. This may cause the comparison of rural with urban production to be overly influenced by the absence of the Kamuli urban production system. Given the apparent prevalence in rural areas is highest in Kamuli (13.5%) it is most likely to be raising the overall rural estimate and hence representing prevalence of *T. solium* cysticercosis in more remote rural systems because of the absence of the urban production system as opposed to a rural system closer to urban systems seen in Masaka and Mukono.

Maximum Likelihood Estimation (MLE) of both test results in both rural and urban production systems provide the estimates of true *T. solium* cysticercosis prevalence, sensitivity and specificity of the two tests (Table 5). Assuming conditional independence of the tests and applying the same parallel interpretation to the MLE results gives a

combined sensitivity (Se) estimate of 63.2% ( $Se1 + Se2 - (Se1 \times Se2)$ ) and specificity (Sp) of 89.4% ( $Sp1 \times Sp2$ ).

**Table 4.5:** Estimation of true *T. solium* cysticercosis prevalence (%), sensitivity and specificity in rural and urban production systems by Maximum Likelihood Estimation (MLE)

	Prevalence	Prevalence	HP10	HP10	ApDia	ApDia
	in rural	in urban	Specificity	Sensitivity	Specificity	Sensitivity
Estimate (%)	0.0	12.3	97.0	53.9	92.2	20.2
95%						
Confidence	0.0 - 3.2	4.2 - 77.5	95.9 – 100	10.1 – 100	90.5 - 93.9	1.5 - 47.7
Interval						

*Note: Test results were assumed to be independent conditional on infection or disease status and have constant sensitivity and specificity in all populations.*

Given the concerns regarding Kamuli we attempted to run the MLE analysis without including this district, unfortunately the number of positive results was then too small to provide any sensible estimates of prevalence, sensitivity or specificity. However, applying the combined Se and Sp estimates to apparent prevalence (AP) of *T. solium* cysticercosis in rural production systems would provide a true prevalence (TP) of 5.5% in Kamuli ( $TP = AP + Sp - 1 / Se + Sp - 1$ ) and zero in Masaka and Mukono. Hence, even with the inclusion of Kamuli potentially raising the estimated true prevalence in rural areas, the confidence intervals for rural and urban production system prevalence do not overlap.

Finally, although the findings of the two assays were different based on the specified protocols described here, this could be due to the different methods used to calculate cut-offs. Table 6 shows a comparison of the seroprevalence values when the same cut-off calculation criteria were used for both tests. The cut-off calculation for ApDia ( $3.5 \times \text{mean ratio} > 1.3$ ) was more stringent than the one for HP10. The application of the ApDia cut-off would result in a reduction of HP10 positives of 64 (96 down to 32), whereas the HP10 cut-off would increase the ApDia positives by 14 (52 up to 66).

**Table 4.6 :** Comparison of observed (apparent) sero-prevalence using HP10 and ApDia assays when the same cut-offs were employed

Type of test	Cut-off Applied for test:	
	ApDia ( $3.5 \times \text{mean ratio} > 1.3$ )	HP10 ( $> \text{negative control mean} + 3 \text{ std. dev.}$ )
ApDia	52 / 1185 (4.4%)	66 / 1185 (5.6%)
HP10	32 / 1185 (2.7%)	96 / 1185 (8.1%)

## 4.5 Discussion

This was the first cross-sectional survey of *T. solium* cysticercosis conducted on a large representative sample of pigs in Uganda, thus adding more information on previous studies (Waiswa *et al.*, 2009 and Nsadhha *et al.*., 2014). It is also the first study directly comparing *T. solium* infection in pigs reared in the rural versus urban settings.

The overall apparent sero-prevalence (12.2%) reported here was lower than previous reports (25.7%) by Nsadhha and others (2014) in Lake Kyoga basin. However, that study

was based on a smaller sample size and the selected study sites were potentially high *T. solium* cysticercosis risk areas near the shore of Lake Kyoga and characterized by factors such as scavenging of pigs, open-air defecation based on previous findings by Nsadhha and others (2010).

Pigs kept under extensive managements systems are prone to parasite transmission (Eshitera *et al.*, 2012; Pondja *et al.*, 2010). Therefore, it might reasonably have been expected that the estimated seroprevalence would have been higher in the latter production system. In fact the reverse was observed in this study, both apparent and true prevalence estimates were lower in rural than urban production systems. It is possible that this could be due to contaminated feeds or water given to pigs.

This study estimated the true seroprevalence of *T. solium* cysticercosis, sensitivity and specificity of the HP10 and ApDia tests using MLE since dissection of pigs for whole carcass cysticerci count was not done due to financial constraints (Dorny, *et al.*, 2004). Compared to the Bayesian statistical approach previously employed by Dorny, *et al.*, (2004) and Krecek *et al.*, (2008, 2011) to estimate true prevalence in absence of a gold standard, MLE was preferable where number of positives was low, agreement between the two tests and informative prior information which could have been used to minimise the challenges of the low number of positives were lacking.

The results indicated that the sensitivity for the HP10 Ag-ELISA was higher than that of the ApDia Ag-ELISA and that both tests do not detect the same antigen. It was suggested

that this may be due to differences in the secretory and excretory products detected by the two assays, which are based on different monoclonal antibody reagents (Krecek *et al.*, 2008, 2011). Variations in the findings of the two Ag-ELISA tests could also be due, to some extent, to differences in the cut-off calculation methods.

The study had some limitations as previously highlighted. One of these was the absence of an urban production system in Kamuli which introduced partial confounding into the prevalence estimates. The ELISA tests used here have been reported to cross-react with *T. hydatigena* which occurs in Uganda, but has only been reported in goats and sheep (Nyakarahuka, 2011, Venkata *et al.*, 2012). However, in Tanzania where it has been reported, its prevalence was low in pigs suggesting its influence on the outcome of these tests could have been minimal (Ngowi *et al.*, 2004).

In conclusion, *T. solium* cysticercosis is present in the three districts examined in this study with sero-prevalence being higher in the urban setting than the rural. The HP10 Ag-ELISA was more sensitive and specific than the ApDia assay. Further parasitological confirmation, either through slaughterhouse studies or detailed *post-mortem* examination of pigs should be done in order to determine the true extent of the problem and verify that the parasite is present. In Uganda, uncontrolled slaughtering of pigs is still common practice. There is need to intensify awareness about the condition and deworming programs targeting both pigs and humans in the whole country regardless of the pig production system. Strict inspection of pork and increased awareness on the importance of proper cooking of pork are needed to minimize transmission.

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## CHAPTER FIVE

### **RISK FACTORS FOR *TAENIA SOLIUM* CYSTICERCOSIS IN PIGS IN MASAKA, MUKONO AND KAMULI DISTRICTS, UGANDA**

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#### **Abstract**

Various prevalence studies on *Taenia solium* cysticercosis have been conducted in recent years indicating occurrence of the infection in pigs and humans populations in Uganda. However, the factors that could be influencing occurrence and persistence of *T. solium* infection in the smallholder pig production systems are not documented.

To determine these factors, a seroprevalence and household survey using a semi-structured questionnaire were conducted in 1185 households in the rural and urban pig production systems in districts of Masaka, Mukono and Kamuli. Odds ratios and p-values were calculated at Confidence Interval (CI) of 95% using logistic regression to measure associations of prospective predisposing factors with the infection.

Findings indicated that crosses and exotic bred pigs had strong association with the disease. Farmers having knowledge about transmission cycle of the condition



significantly reduced it in pigs. Pigs from households that used water from protected sources (borehole, tap, tanks) were 0.525 times less likely to have the condition than those who used unprotected. Pigs in homes without family members unable to use latrine were 0.576 times less likely to have the disease.

Factors that significantly influence occurrence and persistence of *T. solium* cysticercosis in pigs existed. Therefore, there is need to employ strategies that eliminate such predisposing factors thereby interrupting transmission of the condition.

**Key words:** Risk factors, transmission, pigs,

## 5.1 Introduction

*Taenia solium* cysticercosis commonly occurs in pig rearing communities in developing countries. Various factors have been identified to be responsible for the spatial distribution and occurrence of this condition in pigs and humans (Assana *et al.*, 2010; Venkata, *et al.*, 2012). Such factors include: poor hygiene and sanitation practices in humans, free-range pig rearing and tethering, lack of awareness of people about the disease and its transmission, poor or non-inspection of pigs before or following slaughter, use of contaminated water for pigs and people as well as eating of under-cooked pork (Morales, *et al.*, 2008; Nsadh, *et al.*, 2010). Poor hygiene and sanitation have been reported to play a key role in the transmission of *T. solium* cysticercosis in both human and pig populations. Practices such as lack of hand washing with soap following visits to the latrines and before eating food, eating unwashed fruits and vegetables, drinking unboiled /untreated water result in humans ingesting the eggs of *T. solium* and causing porcine cysticercosis (Mwape *et al.*, 2012). Poor sanitation in the households due to open

air defecation, latrines in poor conditions allowing pigs access to faeces increases the possibility of occurrence of the infection (Mwanjali *et al.*, 2013). Faeces deposited in the open environment are often washed into unprotected springs and wells. This contaminates the water sources hence posing a risk to both pigs and humans (Morales , *et al.*, 2008)

The traditional systems of pig rearing commonly practiced in rural communities like free range and tethering play a significant role in maintaining porcine cysticercosis in humans and pig populations. This is because such systems of management allow pigs access to exposed fecal material, thereby enabling the continuity of the *T. solium* lifecycle (Mwape *et al.*, 2012). In Northern Cameroon, where the free range pig management was estimated to be 90.7%, prevalence of the condition was considerably high (26.6%) (Assana *et al.*, 2010).

Lack of appropriate knowledge about *T. solium* cysticercosis and how its transmitted causes reluctance among the communities in ensuring proper hygiene and sanitation, confinement of pigs as well as other practices that limit the spread of this condition (Maridadi *et al.*, 2011). Some reports indicate that people are aware of the infection but are ignorant of how it can be transmitted and controlled (Mutua, Randolph, & Arimi, 2007; Ngowi *et al.*, 2010; Pondja *et al.*, 2010)

The disease has been shown to be prevalent in areas where inadequate or none inspection of pork is practiced (Murrell *et al.*, 2005). This is the case in most communities in Uganda whereby pigs are slaughtered in un-gazetted areas and uninspected pork is then

sold locally or transported to urban centres for marketing (Ouma, *et al.*, 2014). This poses a serious risk to pork consumers especially when they eat undercooked pork. It increases the incidence of taeniosis and the possibility of *T. solium* cysticercosis occurring becomes high (Mwanjali *et al.*, 2013). For this reason, a cross-sectional survey was conducted in Masaka, Mukono and Kamuli districts of Uganda to determine these risk factors and how they influence the occurrence of porcine cysticercosis.

## **5.2 Materials and Methods**

### **5.2.1. Site selection.**

The study was done from April to August, 2013 in Masaka, Mukono and Kamuli districts, Uganda. The process of site selection involved identifying potential districts by Geographical targeting using GIS characterization and spatial analysis. This was followed with a stake-holders' consultative workshop consisting of researchers, farmers, traders where Masaka, Mukono, and Kamuli were selected as the target sites.

At district level, consultative meetings with stakeholders were held in each of the districts to select the study sub-counties, parishes and villages. Twenty two of the villages were selected purposively for the study (Ouma *et al.*, 2014).

### **5.2.2. Sample size calculation.**

The original sample size was calculated to estimate district-level prevalence and considering an infinite population (no recent census data) using the formula adopted from Thrusfield (2007) ,

$n = [Z^2P(1-P)]/d^2$  · and a sample size of 384 pigs for the study in each district was determined. A total of 375, 408, and 402 pigs were sampled in Masaka, Kamuli and Mukono, respectively.

Selection criteria of study sites, description of study area and sampling strategy are reported in detail elsewhere (Ouma et al., 2014).

### **5.2.3. Household questionnaire.**

A questionnaire was administered to the owner of each pig that was bled to assess the risk factors for *T. solium* cysticercosis in the study sites. This questionnaire was adapted from the Cysticercosis Working Group of East and Southern Africa (CWGESA) tool. The questionnaire was pre-tested by the first author on pig farmers from Mukono Municipality before its application to the study sites. It captured data on demographic characteristics, pig production and management, hygiene practices, knowledge and perceptions, as well as treatment of the condition in pigs and humans. Considering that many respondents were not fluent in English, 4 veterinary officers fluent in Indigenous language (Luganda in Masaka and Mukono, Lusoga in Kamuli) were used in each district as research assistants while bleeding of pigs was concurrently done. Prior to the questionnaire administration, the study protocol was explained to the farmer and signed consent obtained. Only 1096 farmers of the 1185 whose pigs had been bled were interviewed. The others who couldn't be interviewed claimed to have commitments and left home immediately their pigs had been bled.

#### **5.2.4. Serology.**

Serological analysis of serum samples was done using HP10 and B158C11A10/B60H8A4 ELISA assays. Every sample that tested positive in either assays contributed to the overall estimated apparent seroprevalence of the condition.

#### **5.2.5. Statistical analysis.**

Data from serology, household questionnaire was entered in Microsoft excel (2010) and exported to the Statistical Package for Social Scientists (SPSS0 software for analysis. Descriptive statistics for the respondents and pig characteristics were determined. A univariable analysis using logistic regression was performed to determine associations between the risk factors and seroprevalence of *T. solium* cysticercosis. Factors with P-values  $\leq 0.1$  were included in a model for multivariable logistic step-wise regression analysis.

A backward elimination procedure was used to exclude the factors one at a time, using  $P > 0.05$  as the criterion. Clustering was accounted for at two levels with district as a fixed variable and village as a random effect in the multivariable models. Model diagnostic was done by checking for normality of residuals at village level, as well as heteroscedasticity of residuals (Dohoo *et al.*, 2012). There was minimal variation between villages considering that village level residuals were all quite small (between -1 and +1). This was also shown by the small value for the village level variance in the final model. Therefore, the fixed effects had very little effect on the size of this variance, implying that even when they were removed from the model, variation between villages still remained limited. Tests for significance of associations and odds ratios were performed at Confidence Interval of 95% and significance level of 0.05.

### 5.3 Ethical Considerations

Approval of study was sought from the Research and Ethics Committee of the College of Veterinary Medicine and Biosciences of Makerere University (Reference number: VAB/REC/13/104) and the Ugandan National Council for Science and Technology (Reference number: HS1477).

### 5.4 Results

Only 1096 (92.5%) pig owners were interviewed out of the 1185 whose pigs were bled. Most respondents ranged from 20 to 60 years, predominantly male (67.97%) and Christians by religion (97.2%). Details of the socio-demographic characteristics of the respondents are in Table 5.1.

**Table 5.1:** Characteristics of respondents and pigs sampled in the three districts

Characteristics	Category	Frequency	Percent
Respondent age-group	<20years	17	1.6
	20-40years	405	37
	41-60year	507	46.3
	>60years	167	15.2
Sex	Female	351	32
	Male	745	68
Religion	Christian	1065	97.2
	Muslim	4	0.4
	SDA	10	0.9
	Traditional beliefs	17	1.6
Ethnic grouping	Baganda	670	61.1
	Basoga	339	30.9
	Banyankole	15	1.4

Level of education	Others	72	6.6
	Never been	114	10.4
	Primary	550	50.2
	Secondary	349	31.8
	Tertiary	83	7.6
Primary activity	Livestock	198	18.1
	Crop farming	747	68.2
	Civil service	38	3.47
	Business	59	5.38
	Others	54	4.93

Several factors at the animal and household level were analyzed for their association with *T. solium* cysticercosis sero-prevalence in pigs in the three districts. At animal level, six variables were assessed using univariable analysis. Only breed type had p-value  $\leq 0.1$  as indicated in Table 5.2.

**Table 5.2:** Univariable analysis of risk factors for *T. solium* cysticercosis at animal level

Factor	Number of pigs	Seropositive pigs (%)	p-value	Odds (95% CI)
Pig category				
Weaner*	455	60(13.2)	-	-
Gilt	25	2(8)	0.457	0.572 (0.132-2.490)
Castrate	178	28(15.7)	0.406	1.229 (0.756-1.999)
Boar	177	17(9.6)	0.218	0.699 (0.396-1.236)
Sow	350	37(10.6)	0.259	0.778 (0.503-1.203)
At least grazed on pasture				
Yes	786	101(12.8)	0.611	0.899 (0.597-1.355)
No*	299	35(11.7)	-	-
Husbandry systems				
Free range	13	1(7.7)	0.354	0.709 (0.342-1.469)
Intensive*	501	59(11.8)	-	-
Tethering	577	75(13)	0.544	0.893 (0.621-1.286)
Breed type				
Local*	195	26(13.3)	-	-
Cross	733	104(14.2)	<b>0.005</b>	2.659 (1.349-5.243)
Exotic	256	14(5.5)	<b>0.000</b>	2.858 (1.604-5.091)

Deworming				
Yes*	797	102(12.8)	-	-
No	388	42(10.9)	0.337	0.829 (0.566-1.215)
Source of pig				
Born on farm*	326	42(13.2)	-	-
Trader	758	89(11.7)	0.746	0.810(0.227-2.898)
NGO/NAADS	15	2(12.5)	0.782	0.821 (0.119-5.675)
Gift	62	7(11.3)	0.591	0.710 (0.119-5.670)
Boar pay	19	3(15.8)	0.604	0.679 (0.157-2.930)

\*Reference variable

At the household level, 10 variables were assessed by univariable analysis. Level of education, knowledge of transmission cycle, water sources, and homes with people who were unable to use latrine facilities had p-values  $\leq 0.1$  as shown in Table 5.3.

**Table 5.3:** Univariable analysis of risk factors for *T. solium* cysticercosis at household level

Factor	Number of pigs	Seropositive pigs (%)	p-value	Odds (95% CI)
Level of education				
None	114	11(9.7)	0.073	0.449(0.187-1.079)
Primary	548	68(12.4)	0.06	0.452(0.197-1.033)
Secondary	348	40(11.5)	0.089	0.593(0.325-1.083)
Tertiary*	83	16(19.3)	-	-
Training in pig management				
Yes*	488	62(12.7)	-	-
No	603	73(12.1)	0.397	0.728(0.348-1.52)
Water sources				
Unprotected*	419	37(8.8)	-	-
Protected	677	98(14.5)	<b>0.008</b>	0.583(0.391-0.870)
Boil water				
Always*	638	79(12.4)	-	-
Never	453	56(12.4)	0.992	1.002(0.695-1.444)
Eating pork				
At least once a month	640	81(12.7)	0.281	0.653(0.3-1.418)
After a month	204	20(9.8)	0.644	0.904(0.587-1.39)
Never*	246	34(13.8)	-	-



Slaughter at home				
Once a year	101	8(16.5)	0.200	0.629(0.31-1.278)
After a year	21	4(19)	0.157	0.583(0.276-1.231)
Never*	957	123(12.9)	-	-
Inspection on slaughter				
Always*	11	0	-	-
Sometimes	20	3(15)	0.59	0.687(0.175-2.692)
Never	111	12(10.8)	0.999	0.000
Presence of latrine				
No	133	3(6)	0.384	0.729(0.358-1.484)
Yes*	1041	132(12.7)	-	-
Unable to use latrine				
Yes	595	90(15.1)	<b>0.006</b>	0.581(0.395-0.855)
No*	458	43(9.4)	-	-
Know transmission cycle				
Yes	121	26(21.5)	<b>0.002</b>	0.463(0.287-0.746)
No*	975	109(11.2)	-	-

---

\*Reference variable

A multivariable logistic regression was performed to ascertain the effects of breed type, level of education, knowledge of transmission cycle, water sources and being unable to use a latrine on the likelihood of pigs having *T.solium* cysticercosis. The model was able to correctly classify 87.6% cases. Compared to local pigs, crosses and exotics had strong association with the disease. Knowledge of the transmission cycle by farmers significantly lowered the condition by 0.476 times. Pigs from households that used water from protected sources (borehole, tap, tanks) were 0.525 times less likely to have the condition than those who used unprotected. Pigs in homes with no family members who were unable to use latrine were 0.576 times less likely to have disease as in Table 5.4.

**Table 5.4:** Multivariable analysis of animal and household level risk factors for *T. solium* cysticercosis

Variable	B coefficient	P-Value	Odds ratio (95% CI)
Breed type			
Local	Reference		
Cross	1.17	0.001	3.221 (1.599-6.488)
Exotic	1.135	0.000	3.110 (1.733-5.580)
Level of education			
None	Reference		
Primary	-0.687	0.111	0.503 (0.216-1.172)
Secondary	-0.443	0.161	0.642 (0.345-1.194)
Tertiary	-0.542	0.104	0.582 (0.303-1.118)
Knowledge of transmission cycle			
Yes	-0.743	0.003	0.476 (0.291-0.779)
No	Reference		
Water source			
Unprotected	Reference		
Protected	-0.644	0.020	0.525 (0.350-0.787)
Unable to use latrine			
Yes	Reference		
No	-0.551	0.006	0.576 (0.389-0.853)

## 5.5 Discussion

Whereas several studies have reported that free range pig rearing, absence of a latrine, home slaughters and non-inspection are significantly associated with prevalence of *T. solium* cysticercosis, none of these factors had a significant association with the condition in our study(Assana *et al.*, 2010; Eshitera *et al.*, 2012; Morales, *et al.*, 2008; Nsadha, *et al.*, 2010).

The odds of exotic and crossed pigs having the *T. solium* cysticercosis infection were significantly higher than local ones. Similarly, Krecek and others (2012) reported a significantly high seroprevalence among the crossbred pigs than local ones (Ouma *et al.*, 2014). The pig breed types referred to here as local are those that have been reared for

decades by farmers in the communities and are characterized by slow growth. They have adapted to the harsh conditions over time and are usually resilient to diseases which is not the case with recently introduced breeds or their crosses (FAO, 2012). It is likely that *T. solium* cysticercosis in the local pigs is self-limiting unlike in the other breed types.

Seroprevalence of *T. solium* cysticercosis in pigs significantly reduced in homes that used protected water sources. This is in agreement with a study in Mexico where use of stagnant water in pigs significantly increased the condition in pig population (Morales, *et al.*, 2008). Likewise, studies in Tanzania and Rwanda reported use of water from unprotected sources as an etiological factor for the condition (Mwanjali *et al.*, 2013; Rottbeck *et al.*, 2013). In case contamination of the environment with *T. solium* eggs was to occur, possibility for pigs and humans ingesting them is high when water from open sources such as rivers, streams, wells, and lakes is used in the homes without boiling or using decontaminating chemicals like chlorine (Morales, *et al.*, 2008). Although not reported as significant in other studies, not boiling drinking water was strongly associated with occurrence of the infection in pigs. The practice limits the *T. solium* cycle by destroying eggs which could be directly ingested in water by both pigs and humans to cause taeniosis-*T. solium* cysticercosis.

No study has reported the key role played by the people who are unable to use latrines in homes where these facilities exist, a factor which has been found to be significantly associated with porcine cysticercosis seroprevalence in this study. Children under age of

5 years, weak recumbent people (the old and sick) tend to carelessly defecate anywhere thereby increasing the risk of environmental contamination with the *T. solium* eggs.

Community awareness about a disease is important for its control (Murrell *et al.*, 2005) . This was the case in our study whereby knowledge of the transmission cycle by farmers reduced likelihood of *T. solium* cysticercosis in pigs. Likewise, a study in Tanzania demonstrated that sensitization of pig keeping communities resulted in a significant reduction of the condition in pigs (Ngowi *et al.*, 2008).

## **5.6 Conclusion**

This study indicates that a number of factors associated with etiology and persistence of *T. solium* cysticercosis exist in pig production systems in Uganda. Therefore, following confirmation by conducting large scale epidemiological studies involving other districts in the country, these factors could be targeted for eradication of the condition. Special considerations should be made during construction of latrines for children, old people and humans with disabilities. Use of water from protected sources should be encouraged in these communities. Upscaling programs of sensitization of communities about the pig tapeworm and its public health importance should be done to raise awareness.

More studies on taeniosis and human cysticercosis prevalence and risk factors need to be conducted so as to draw holistic control strategies for the disease.

## **Acknowledgements**

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## CHAPTER SIX

### **PERCEPTIONS AND PRACTICES OF FARMERS ON *TAENIA SOLIUM* CYSTICERCOSIS AND ITS CONTROL IN MASAKA, MUKONO AND KAMULI DISTRICTS, UGANDA**

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#### **Abstract**

*Taenia solium* cysticercosis is endemic in Uganda and there is lack of knowledge of pig farmers on the transmission cycle. A cross sectional study was conducted to determine perceptions and practices of farmers regarding taeniosis, human cysticercosis and porcine cysticercosis as well as their control. A questionnaire was administered to 1096 pig farmers in Masaka, Mukono and Kamuli districts.

The results indicated that farmers were mostly aware about taeniosis (63.0%; 95% Confidence Interval=60.0-65.8) with only 3/1096 (0.3%, 95% CI=0.1-0.8) having knowledge on all three conditions. Key practices such as deworming of pigs and humans, as well as hand washing that are important in controlling taeniosis-*T. solium* cysticercosis complex were assessed. Farmers reported that they dewormed their pigs (94.1%) more

than themselves and their family members (62.0%). Albendazole was the most used drug for deworming both pigs and humans (85% and 81.5% respectively). The proportions of responses of farmers on deworming practices varied significantly among the districts of Kamuli, Masaka and Mukono. More than a half (54.6%) of the farmers interviewed had clean water near the latrines designated for washing hands. Of these, only 41.9% used water with soap to wash hands after latrine use. Availability of both water and soap varied significantly among the three districts ( $X^2=16.944$ ,  $P<0.05$ ).

Generally, farmers had some knowledge about the disease but could not make the link between taeniosis, human cysticercosis and porcine cysticercosis. Raising awareness on the taeniosis- *T. solium* cysticercosis transmission cycle could help in the management of the pork tapeworm conditions.

**Key words:** Perceptions, pig, taeniosis, *T.solium* cysticercosis, control, Uganda.

## 6.1 Introduction

Community awareness about a disease is a crucial step in its control and eventual eradication. Lack of knowledge about the pork tapeworm transmission cycle by farmers, consumers and non-consumers of pork, medical and veterinary personnel, policy makers and implementers in developing countries has made control of the potentially eradicable condition difficult( Ngowi *et al.*, 2008). Limited knowledge has led to increasing incidence among rural poor pig-keeping communities (Assana *et al.*, 2010; Ngowi *et al.*, 2010). Neuro-cysticercosis, a condition that occurs following migration of *T. solium* larvae to the brain has been reported as the commonest cause of adult-onset epilepsy in poor pig-keeping communities (Willingham & Mugarura, 2008; Mwanjali *et al.*, 2013). It

is estimated to cause up to 30% of epilepsy cases of known causes in Sub Saharan Africa ( Ngowi *et al.*, 2013). Figure 6.1 illustrates the transmission cycle of *T. solium* condition.

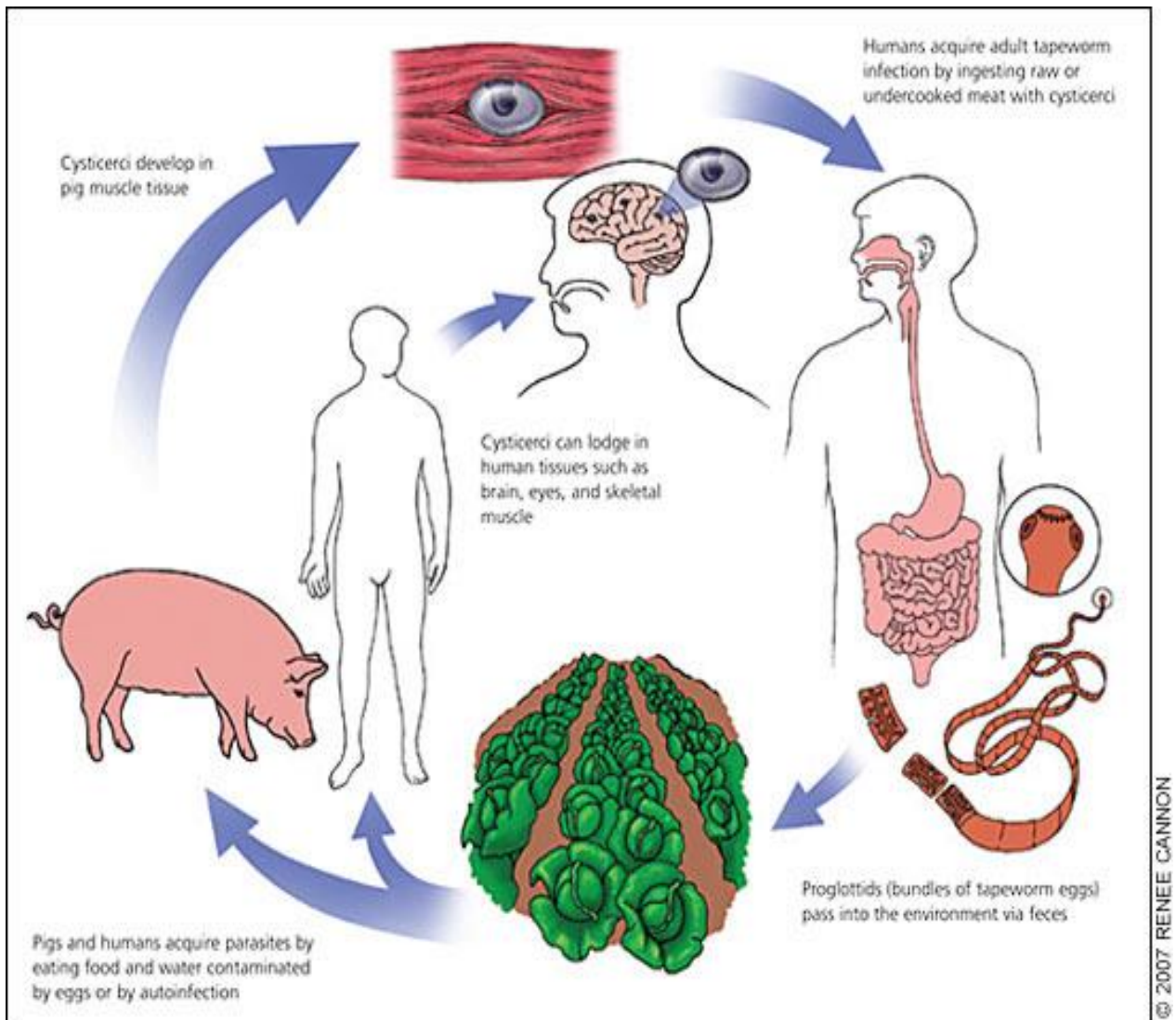


Figure 6.1: The life cycle of Taeniosis-*T. solium* cysticercosis complex (Retrieved from Ngowi et al., 2013)

Local people, health and veterinary personnel in endemic areas may know about tapeworm infections in humans but may not relate it with porcine cysticercosis and neuro-cysticercosis (Phiri *et al.*, 2002). In Uganda, misperceptions such as “tapeworm



*infections are only caused by eating of raw sweet potatoes and cassava*” are common in the local communities. Misleading reports by misinformed media reporters who allege that “*eating pork directly causes epilepsy*” could contribute to the complication of the control of *T. solium* infection (Newvision, 2014) .

Although change of behaviour in communities is not automatic after acquisition of knowledge, it could be a key step in prevention of *T. solium* cysticercosis (Krecek *et al.*, 2012; Maridadi *et al.*, 2011). Given the importance of pig rearing and pork consumption in Uganda, it would be useful to assess how pig farmers perceive the infection in their community. Therefore, this study aimed to investigate perceptions and practices of farmers regarding taeniosis and *T. solium* cysticercosis in order to inform future control initiatives of the disease in Uganda.

## **6.2 Materials and methods**

### **6.2.1. Study design.**

#### **Study sites**

The study was done from August 2012 to May 2013 in Masaka, Mukono and Kamuli districts, Uganda. Masaka district is located in central region and has the highest pig population (181,846 pigs) in the country (MAAIF, 2011). Mukono which is located 20 km away from Kampala, Uganda’s capital city where most pork is sold has up to 181,846 pigs (Ouma, *et al.*, 2014). Kamuli, with about 55,239 pigs is known to harbour hotspots of *T. solium* cysticercosis (Nsadha, *et al.*, 2014). Generally, the potential for transmission of the pig tapeworm in the selected study sites was high.

These districts were selected as part of the Small holder Pig Value Chain Development project (SPVCD) study which has been undertaken by the International Livestock Research Institute (ILRI) in Uganda. Consultative meetings with district stakeholders were held in each of the districts to select the study sub-counties, parishes and villages. For each district, 2 sub-counties were selected to represent the rural and urban value chain domains. Within each selected sub-county, 2 to 3 villages were randomly selected for the pig value chain activities. A total of 35 villages were selected for the project value chain assessment activities. For this study, 22 villages out of the 35 were selected purposively across the three districts. The number of villages was based on financial resources available and also to coincide with other activities taking place in the same villages, to avoid farmer's fatigue. Selection of study sites was described in detail elsewhere (Dione *et al.*, 2014; Ouma *et al.*, 2014).

### **Sample size determination**

The sample size derived from a cross-sectional survey undertaken to determine the prevalence of *T. solium* cysticercosis in the selected districts. It was calculated considering an infinite population (no recent data) using the formula adopted from Thrusfield (2007) as follows:  $n = [Z^2P(1-P)]/d^2$ . Therefore, a sample size of 384 farmers was required for the study in each district. However, to increase precision, a sample size of 400 respondents in each district was considered. A total of 375, 342, and 379 farmers keeping pigs were interviewed in Masaka, Kamuli and Mukono districts for the study. This was because some farmers had left their homes to attend to engagements in distant places where they could not be accessed

### **6.2.2 Collection of data.**

Data was collected from 1096 farmers by face-to-face interviews using a questionnaire. This questionnaire was adapted from the Cysticercosis Working Group of East and Southern Africa tool ([www.cwgesa.dk/CWGESA/Action](http://www.cwgesa.dk/CWGESA/Action)). It was pre-tested by the first author with pig farmers from Mukono municipality before its application in the study sites. Information addressing perceptions on taeniosis and *T. solium* cysticercosis, as well as practices on management of the condition in pigs and humans were captured.

Considering that many respondents were not fluent in English, veterinary officers fluent in indigenous languages (Luganda in Masaka and Mukono and Lusoga in Kamuli) were trained to administer the questionnaire in each district. Prior to the questionnaire administration, the study protocol was explained to the farmer who signed a consent form if they agreed to participate.

### **6.2.3. Statistical data analysis.**

Data collected was entered in the Census and Survey Processing system (CSPRO) software version 4.1 for cleaning and coding. It was then exported to the Statistical Package for Social Scientists (SPSS) version 16 for analysis. Descriptive statistics for the responses were generated. Performance scores were calculated for each of the five different variables used to assess knowledge on taeniosis, porcine cysticercosis and human cysticercosis as described by Dohoo (Dohoo, Martin, & Stryhn, 2009). Briefly, weights of 0-10 points were subjectively assigned as overall scores to the responses on questions assessing each knowledge variable. A respondent was considered to have knowledge on a particular variable when his/her responses scored 8-10 points and these were then

recoded into dichotomous variables (have knowledge verses no knowledge). Proportions of farmers with knowledge on the three conditions were described using a histogram.

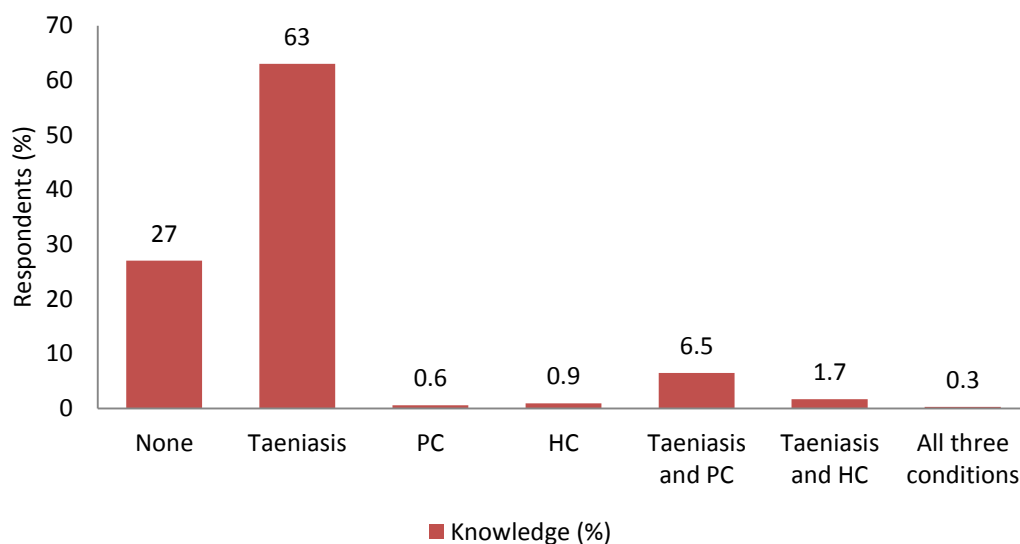
### **6.3 Ethical Considerations**

Approval of study was sought from the Research and Ethics Committee of the College of Veterinary Medicine Animal Resources and Biosciences of Makerere University (Reference number: VAB/REC/13/104) and the Ugandan National Council for Science and Technology (Reference number HS1477).

### **6.4 Results**

#### **6.4.1. Farmers' perceptions of the three conditions.**

A knowledge performance score was conducted on the 1096 farmers' responses about taeniosis, human cysticercosis and porcine cysticercosis (Table 1). The proportions of the five different knowledge variables were calculated. Generally, farmers had highest knowledge on taeniosis (63.0%, 95% CI=60.0-65.8) compared to other conditions. Only 3/1096 (0.3%, 95% CI=0.1-0.8) respondents had knowledge about all three conditions as described in figure 6.1 and Table 6.1.



**Figure 6.1:** Percentage responses on knowledge of taeniosis, Porcine cysticercosis, Human cysticercosis

**Table 6.1:** Proportions of the different variables used to assess level of knowledge on taeniosis, human cysticercosis and porcine cysticercosis

Knowledge variable	Taeniosis, n (%)	Human cysticercosis, n (%)	Porcine cysticercosis, n (%)
How condition clinically manifests	782 (71.4)	56 (5.1)	319 (29.1)
How condition is acquired	780 (71.2)	22 (2.0)	127 (11.6)
Organs affected	683 (62.4)	32 (2.9)	127 (11.6)
Effects of condition	683 (62.4)	56 (5.1)	11 (1.0)
How to control condition	658 (60)	22 (2.0)	38 (3.5)

Male farmers had more knowledge about the three conditions compared to females.

Farmers of Kamuli district, the most rural area of the study sites had the least knowledge about the pig tapeworm conditions compared to Masaka and Mukono districts. Table 6.2 shows the details of these finding.

**Table 6.2:** Average proportions of knowledge on taeniosis, porcine cysticercosis and human cysticercosis by gender, level of education and districts of origin of farmer respondents

Categories	Taeniosis (%)	Porcine cysticercosis (%)	Human cysticercosis (%)
Gender			
Male	495/745 (66.4)	107/745 (14.4)	29/745 (3.9)
Female	223/351(63.5)	18/351 (5.1)	8/351 (2.2)
Level of education			
None	71/114 (62.3)	18/114 (15.8)	4/114 (3.5)
Primary	344/550 (62.6)	71/550 (12.9)	19/550 (3.5)
Secondary	224/349 (64.2)	18/349 (5.2)	12/349 (3.4)
Tertiary	79/83 (95.2)	18/83 (21.7)	2/83 (2.4)
District			
Kamuli	160/400 (40.0)	40/400 (10.0)	6/400 (1.5)
Masaka	259/324 ( 79.9)	67/324 (20.7)	16/324 (4.9)
Mukono	293/372 (78.8)	18/372 (4.8)	15/372 (4.0)

#### 6.4.2. Control practices.

Key practices such as deworming of pigs and humans, as well as hand washing that are important in controlling taeniosis-*T. solium* cysticercosis complex were assessed. Farmers reported that they dewormed their pigs (94.1%) more than themselves and their family members. They declared that albendazole was the most used drug for deworming both pigs and humans (85% and 81.5% respectively). The proportions of responses of

farmers on deworming practices varied significantly among the districts of Kamuli, Masaka and Mukono (Table 6.3).

**Table 6.3:** Proportions of responses on deworming practices associated with control of *T. solium* cysticercosis in Kamuli, Masaka, Mukono districts

Deworming practice	Kamuli	Masaka	Mukono	Total, n (%)	X <sup>2</sup>	P-value
<b>Deworm pigs</b>					4.295	0.000
Yes	303	357	371	1031 (94.1)		
No	39	18	8	65 (6.3)		
Deworm pigs how often					3.495	0.000
3 months interval	94	178	216	488 (44.5)		
Once a month	131	110	93	334 (30.5)		
>3 months interval	84	64	61	209 (25.0)		
Drugs used						
Albendazole	122	229	209	932 (85.0)		
Ivermectin	33	23	108	164 (15.0)		
<b>Deworm self and family</b>					4.97	0.000
Yes	143	244	293	680 (62.0)		
No	197	129	90	416 (38.0)		
How often					2.338	0.000
Once a month	44	50	20	114 (16.8)		
3 months interval	42	117	167	326 (47.9)		
>3 months	57	77	106	240 (35.3)		
Drugs used					2.492	0.000
Albendazole	122	228	204	554 (81.5)		
Ivermectin	0	1	0	1 (0.15)		
Praziquantel	0	0	5	5 (0.74)		
Others	23	13	84	120 (17.7)		

Hand washing, one of the key measures that limit the taeniosis-*T.solium* transmission cycle was assessed. More than a half (54.6%) of the farmers interviewed had clean water near the latrines designated for washing hands. Of these, only 41.9% used water with soap to wash hands after latrine use. Availability of both water and soap varied significantly among the three districts ( $X^2=16.944$ ,  $P< 0.05$ ) (Table 6.4).

**Table 6.4:** Proportions of responses on hand washing practices associated with control of taeniosis-*T. solium* cysticercosis

Practice	Masaka	Mukono	Kamuli	Total, n (%)	$X^2$	P-value
Practice hand washing					0.698	0.706
Yes	203	201	194	598 (54.6)		
No	185	163	150	498 (45.4)		
Presence of clean water and soap					16.944	0.00
Both present	172	174	113	459 (76.8)		
Only water present	217	200	220	139 (23.2)		

## 6.5 Discussion

Adoption of better practices that limit risks of taeniosis-*T. solium* cysticercosis is highly influenced by awareness of the transmission cycle of the complex. In this study, farmers' perceptions and practices on the public health problem were determined to understand better how low cost, yet effective strategies could enable poor pig keeping communities get rid of this condition ( Ngowi *et al.*, 2008).



This study indicated that awareness of taeniosis was high among farmers in Uganda, as compared to Tanzania, where a lower proportion of people (31.2%) were aware of taeniosis (Maridadi *et al.*, 2011).

Generally knowledge on human cysticercosis was very poor, a finding that agreed with the report that a slightly higher proportion of 20% of farmers in Tanzania were aware that epilepsy could result from *T. solium* cysticercosis (Maridadi *et al.*, 2011). This could complicate any efforts of controlling the most preventable cause of epilepsy in the sub-Saharan African region ( Willingham & Mugarura, 2008) . Respondents who had knowledge on all the three conditions were the least. This demonstrated that majority of farmers were unable to link the development stages of the pig tapeworm hence making breaking of the transmission cycle difficult.

Male farmers had more knowledge about the three conditions compared to females. This could be attributed to the more exposure men have at social gatherings unlike the women who are mostly involved in domestic work (Ouma *et al.*, 2014).

Most farmers who were deworming themselves and their pigs routinely using drugs, demonstrated the success achieved when chemotherapy was used as part of the control strategies (Mkupasi, *et al.*, 2013; Pondja *et al.*, 2012). This practice could have played a key role in limiting the transmission cycle of the taeniosis-*T. solium* cysticercosis complex in Masaka, Mukono and Kamuli districts. According to the farmers, the practice was being implemented not necessarily because of their awareness about the specific dangers of *T. solium* cysticercosis but as a way of controlling worm infestations that were

known to hinder growth of the pigs and cause humans to get hungry shortly after a meal (Kolaczinski, *et al.*, 2006).

Latrine use has in the recent years been highly promoted in all the districts in Uganda by the Ministry of Water and Environment with an overall access to a basic latrine estimated at 74.6% (Republic of Uganda, 2014). Although a moderate proportion of farmers reported to practice hand washing in their homes in the three districts, the practice in the entire country was estimated to be still low (32.7%) according to a recent report (Republic of Uganda, 2014). The effectiveness of the hand washing practices could be minimal due to less use of soap. Hand washing with soap, latrine use, and safe water use are considered by WHO as the key hygiene behaviours that limit the burden of infectious conditions like taeniosis-*T.solium* cysticercosis (Aiello & Larson, 2002).

## **6.6 Conclusion**

It was therefore concluded that many farmers in Masaka Mukono and Kamuli have some understanding about the *T. solium* cysticercosis but making the link between taeniosis, human cysticercosis and porcine cysticercosis posed a challenge.

Although it may not be cheap or a very effective strategy on its own, appropriate health education of local communities on the transmission cycle of this condition might enhance good practices such as proper hygiene and sanitation, use of water from protected sources, boiling of drinking water, as well confinement of pigs.

Public health sensitization through media in local languages (television, radios and newspapers), display of posters with well-illustrated taeniosis-*T.solium* complex

transmission cycles in public places as well as including it in school curriculum could be essential in raising awareness.

A holistic approach drawing together veterinary, medical and public health professionals involved in activities to control taeniosis-*T.solium* conditions should be envisaged to make such efforts cheaper yet more effective.

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## CHAPTER SEVEN

### GENERAL DISCUSSION

#### **Significance of *T. solium* cysticercosis**

An elaborate understanding of the pattern of *T. solium* cysticercosis in the prone countries in the world has been presented as part of the study of a barely prioritized yet highly devastating condition. The socioeconomic losses and health defects are high where quantification of the disease effects has been done. Lack of a clear understanding of the development and transmission cycle of the pig tapeworm by the vulnerable local communities and even the technical people (Medical and veterinary personnel). There is lack of political will in most of the affected countries probably due to high economic constraints. Except the United Republic of China in South East Asia, Mexico and Peru in Latin America where well-outlined control strategies of the disease are being implemented many affected countries are not bothered. Since the condition is zoonotic, application of a synergistic one-health approach that draws all stakeholders together could be essential in disrupting the *T. solium* life cycle.

#### **Porcine cysticercosis prevalence and associated risk factors**

Prevalence of *T. solium* cysticercosis (15.8 %) here is within the range of the previously reported and it is an indicator that it is endemic in pigs in Uganda. This prevalence estimate is the lowest among the recent studies conducted in African countries. This however can not create laxity but should instead be an awakening to the stakeholders to initiate the process of eradication of the condition in both pigs and humans. Except for Kamuli, the distribution of the infection basing on the 2 antigen tests was similar within

the districts of study. This could imply that despite the geographical location, prevalence of *T. solium* cysticercosis in pigs of other districts is within estimates made in this study. According to the production settings, seroprevalence of the infection in pigs in the rural was significantly high and likewise the risk factors compared to other settings. This could probably be attributed to the high poverty levels which amplify predisposing factors such as poor management practices and open air defecation in the rural communities. Risk factor for *T. solium* cysticercosis assessed in this study are few and probably explains the low prevalence of disease in pigs of Masaka, Mukono and Kamuli districts reported. Therefore, increasing efforts to eliminate the risk factors would disrupt the transmission cycle the *T. solium* complex and offer an opportunity for complete eradication of the condition in the study area and the country as a whole.

The prevalence study had some limitations. There was lack of a reliable diagnostic test that could be used as a gold standard imploring the use of a Maximum Likelihood Estimation statistical modelling to obtain a true prevalence. Out of the 1185 households randomly selected to participate in the study, 89 farmers were not interviewed. The prevalence and risk factors reported here may not necessarily be the same throughout the country due to the different socio-demographic patterns of the different regions.

### **Risk factors for Taeniosis-*T. solium* cysticercosis complex at the consumer level**

Kampala district was a hub for pork from many pig keeping communities in the country. Except in the Kampala Central (business centre) pork outlets and demand of pork had increased in the different divisions. This could be propagating occurrence of taeniosis and

*T. solium* cysticercosis among the human and pig populations in the district. The district lacked a reliable and well gazetted abattoir for pig slaughters meaning there was a lack of meat inspection and proper hygiene practices were not taken seriously. Tapeworm carriers among those handling pork and serving ready to eat pork with raw salads at retail outlets could be playing a key role in maintaining the taeniosis-*T. solium* cysticercosis complex in the city with highest human population of a diverse background. The limitation of this study was the refusal of some of the pork outlet owners to take part in the study.

### **Perceptions and practices related to taeniosis and *T.solium* cysticercosis and its control**

Having knowledge about a disease and how it is transmitted is a very crucial step in controlling it. This study indicates that awareness of taeniosis was high among farmers, however their limited knowledge about *T. solium* cysticercosis in pigs and humans clearly indicate that they do not have adequate knowledge on the transmission cycle. Despite this, the routine practice of farmers deworming themselves and pigs has been useful in limiting the transmission cycle of the taeniosis-*T. solium* cysticercosis complex, although this could have been implemented not necessarily because of their awareness but have heard that pigs are dirty and close association with them leads to worm infestations.

The limitation of this study was that the farmers or relatives who reported to have suffered from epilepsy and lumps could not give details of the line of treatment used. This could probably have been because they went to traditional healers instead of hospital

since the condition is always associated to witchcraft. The number of epilepsy cases could also have been underestimated because of some farmers who feared to share such scary experiences. Epilepsy and lumps under the skin do not necessarily imply that the affected people suffered from human cysticercosis.

## **Recommendations**

Until now, the process of applying short and long-term intervention strategies to eradicate taeniosis and *T. solium* cysticercosis continues in affected countries following a statement by the International Task Force for Disease Eradication (ITFDE) in 1993. According to ITFDE, the condition is eradicable because; it's lifecycle requires only two hosts (humans and pigs), pig carriers (intermediate host) are usually slaughtered by one year, no known significant wildlife reservoir, cheap and effective drugs for treatment of infection in man. The infection no longer occurs in Europe where intensive control measures have been employed before and significant reduction of *T. solium* transmission in human and pig populations following chemotherapy has already been demonstrated.

Despite this, other than lowering of prevalence in humans and pig populations of countries where interventions have been employed, total elimination of the condition has not yet been achieved (Murrell *et al.*, 2005).

Basing on the findings in this study and political will as well as economic situation observed in the country, the following strategies when implemented could lead to a tremendous disruption of the transmission and possible eradication of the disease in Uganda. They include;

- i. General education about *T. solium* to stakeholders along the pig value chain including farmers, traders, consumers, government policy makers, committees involved in resource allocation and training institutions.
- ii. Since the use of anthelmintics for treatment of humans and pigs is ongoing in the country, emphasis on the appropriate drug, dosage and period of protection as well as assessment of impact of this intervention must be ensured by the medical and veterinary practitioners. Drugs such as albendazole, ivermectin, praziquantel were being used in both humans and pigs with considerable effects as reported by Murrell and others (2005). However, oxfendazole which has been demonstrated by previous studies (Gonzalez *et al.*, 2001; Iburg *et al.*, 2012; Pondja *et al.*, 2012; Sikasunge *et al.*, 2008) to have better efficacy could be preferred. These programs should involve use of up-to-date highly specific and sensitive diagnostic tools, and clinical management procedures.
- iii. Establishment and enforcement of appropriate standards of meat hygiene and inspection by food safety policy makers and implementers. Low cost slabs specific for pigs should be constructed in every division in Kampala where inspection of pigs can be done following slaughter.
- iv. Special considerations should be made for vulnerable weak groups such as children and the old people during construction of latrines to minimize open defecation.
- v. Regardless of the source, all the water for house hold use should be boiled to kill the *T. solium* eggs.

Generally, for the strategies suggested here to be effective, a synergistic approach



involving policy makers, medical personnel, veterinarians, food safety specialists in the country should be embraced.

Future research should be undertaken in the following areas:

- Carry out extensive epidemiological surveys in pigs and humans in the different regions of the countries since they usually have varying socio-demographic patterns and possibly with different disease predisposing factors.
- Medical and veterinary sectors should undertake joint national prevalence and economic impact studies.
- Testing intervention measures discussed here and assessing their impact on the taeniosis-*T. solium* complex.

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## APPENDICES

### **Appendix I: Household questionnaire used to collect data on taeniosis-*T. solium* cysticercosis**

#### **General information**

Last name : \_\_\_\_\_ First Name :

\_\_\_\_\_

If Child then : Questionnaire number :

\_\_\_\_\_

Father's Name : \_\_\_\_\_ District

\_\_\_\_\_

Division:

\_\_\_\_\_

Mother's Name: \_\_\_\_\_ Location:

\_\_\_\_\_

Sub-location:

\_\_\_\_\_

Village

\_\_\_\_\_

GPS Reading North: \_\_\_\_\_ (Format N00.xxxxx)

East:: \_\_\_\_\_ (Format E00.xxxxx)

Altitude: \_\_\_\_\_(Format xxxx m)

1. How old are you? \_\_\_\_\_ (years)
2. Sex ☐ Male ☐ Female
3. What is the highest schooling grade you have completed?  
☐ None ☐ Primary school  
☐ O'Level ☐ A'Level ☐ Institution
4. What is your occupation?  
\_\_\_\_\_

5. Have received any special training on pig production?

☐Yes ☐No

If yes, specify the type of training. \_\_\_\_\_

6. What was the length of the training?

☐ <1week ☐ 2-4weeks ☐ >4weeks

**A. Pig production systems and management practices**

7. How many pigs do you keep? Boar\_\_\_\_Sow\_\_\_\_Piglet male\_\_\_\_Piglet  
female\_\_\_\_ Gilt\_\_\_\_ Castrate-fattener\_\_\_\_

8. What is the production system practiced?

☐Free range ☐Tethering-under tree shade ☐Tethering-on pastures ☐Backyard  
confinement

☐Intensive-raised floors ☐Intensive-Uncemented floors ☐Intensive-Cemented floors

9. Feed type

☐Crop residues ☐Swill ☐Commercial feeds ☐Pastures

10. Routine disease prevention measures.

☐None ☐Spraying ☐Deworming ☐Other prophylaxis\_\_\_\_\_

## B. Hygiene and sanitation

11. Where do you usually get your drinking water?

- ☐ River ☐ Bore-hole  
☐ Well ☐ Other (please specify) \_\_\_\_\_

12. Do you boil your drinking water?

- ☐ Always ☐ Almost always  
☐ Sometimes ☐ Never

13. Do you have a latrine at home?

- ☐ Yes ☐ No (Skip to Q 14)

13.1 How often do you use a latrine when you have to defecate?

- ☐ Always ☐ Sometimes ☐ Never

14. Do you have children <6years and old people unable to use the latrine?

- ☐Yes ☐No

14.1If yes, how do you dispose the feaces?

- ☐ Pit latrine ☐ Digging a hole ☐ Thrown in the near bushes

15. What is the general latrine coverage in the village (Interview to get details from LC1)

Table below to completed by interviewer following observations

Facility	Guide to grading	Status	Comment (Excellent, Good, Poor)
Pit latrine	Available, well built with strong walls , door and roof. Well ventilated, hole		

	clean and covered		
Hand washing	Container with clean water available. Soap/detergent available		
General home cleanliness	Compound clean. Rubbish pit present. House clean. A raised drying stand for plates, cups and pans present		

### C. Knowledge, Attitudes and Practices of farmers in relation to *T.solium* cysticercosis

16 .How often do you eat pork?

- ☐ At least once a month
 ☐ Less than once a month but at least once a year  
☐ Less than once a year
 ☐ Never

17. How is the pork that you eat prepared? [*Check all that apply.*]

- ☐ Boiling
 ☐ Barbeque  
☐ Fried
 ☐ Others

(specify)\_\_\_\_\_

18. How often do you slaughter pigs at home?

- ☐ At least once a month
 ☐ Less than once a month but at least once a year  
☐ Less than once a year  
☐ Never
 ☐ Can not remember, do not know



18.1 If ever, how often was the meat inspected by a meat inspector?

- ☐ Always ☐ Almost always  
☐ Sometimes ☐ Never  
☐ Can not remember, do not know


19 .What price do you usually sell your pigs when they are ready to be slaughtered (specify the currency used, this can be money or barter)? \_\_\_\_\_  
\_\_\_\_\_

20. What price do you usually sell your piglets (aged 4 months or less) (specify the currency used, this can be money or barter)?  
\_\_\_\_\_  
\_\_\_\_\_


21. Were you ever told that your pigs or piglets were infected with cysts (cysticercosis)?

- ☐ Yes ☐ No

21.1 When were you told that your pig or piglets were infected with cysts (cysticercosis)?

- 
- ☐ In the past year ☐ One (1) to five (5) years ago  
☐ More than five (5) years ago  
☐ Never told ☐ Can not remember, do not know

21.2 When that happened, were you able to sell your pig(s) or piglets?

- 
- ☐ Sold both ☐ Sold pigs but not piglets  
☐ Sold piglets but not pigs  
☐ Could not sell either  
☐ Can not remember, do not know



21.3 When that happened, what price did you sell your pigs (aged more than 4 months) (specify the currency used, this can be money or barter)?

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

21.4 When that happened, what price did you sell your piglets (aged 4 months or less) (specify the currency used, this can be money or barter)?

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

22. Have you ever seen or heard of white nodules (rice) in pig carcasses?

☐ Yes

☐ No (Skip to 18)

22.1 Where can you find nodules on a live pig?

☐ It is not possible to find them on a live pig

☐ Under the skin

☐ Under the tongue

☐ I don't know

☐ Somewhere else (Specify) \_\_\_\_\_

22.2 How do pigs get these nodules?

☐ By eating human faeces

☐ By eating pig faeces

☐ From another infected pig

☐ Other (Specify) \_\_\_\_\_

☐ I don't know

22.3 What would you do if you discovered that your pig had nodules?

☐ Sell the pig

☐ Treat it with herbs

☐ Pierce the nodules ☐ Other (Specify)

---

☐ I don't know

23. Have you ever heard of tapeworm infection in humans?

☐ Yes ☐ No (Skip to question 19)

23.1 How did you learn about it?

☐ By a doctor ☐ By a friend or family member

☐ By a traditional healer ☐ On the radio / newspaper

☐ Other (Specify) \_\_\_\_\_

23.2 How does a person know if they have a tapeworm?

☐ They can see it in their faeces ☐ They have diarrhea

☐ They have fever ☐ Other (Specify)

---

☐ I don't know

23.3 Have you ever had a tapeworm or seen small parts (segments) of worms in your faeces? (*Show photographs of proglottids*)

☐ Yes ☐ No (SKIP TO Q 18.4)

☐ I don't know/can not remember (SKIP TO Q 18.4)

23.3.1 When that happened, what did you do? [*check all that applies*]

☐ Went to a primary health care provider (hospital, clinic, dispensary)

☐ Went to the pharmacy to get a drug to treat it

☐ Went to a traditional healer ☐ Did nothing

☐ I can not remember, I do not know

23.4 How does a person get tapeworm infection?

- ☐ They do not wash their hands                      ☐ They eat undercooked pig meat
- ☐ They are in contact with an infected person                      ☐ Other                      (Specify)

\_\_\_\_\_

- ☐ I don't know

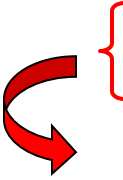
24. Have you ever had skin nodules or hard lumps under the skin? (*Show photograph of person with subcutaneous cysticercosis nodules*)

- ☐ Yes, currently has    ☐ Yes in the past year, but not currently
- ☐ Yes, one year or more ago, but not currently                      ☐ No
- ☐ Can not remember, do not know

24.1 Were you ever told that you had epilepsy or that you had had an epileptic seizure?

- ☐ Yes, currently has    ☐ Yes in the past year, but not currently
- ☐ Yes, one year or more ago, but not currently                      ☐ No
- ☐ Can not remember, do not know

25. Is there someone in your household with epilepsy or seizures?

-  ☐ Yes, currently is    ☐ Yes in the past year, but not currently
- ☐ Yes, one year or more ago, but not currently                      ☐ No

25.1 (If yes) Who in your household has epilepsy or seizures? [*check all that apply*]

- ☐ Mother    ☐ Father
- ☐ Brother/sister    ☐ Child

☐ Other relative                      ☐ Other (specify) \_\_\_\_\_

26. Have you ever consulted a health provider because of this condition?

☐ No            (skip to Q 27)                      ☐ Cannot remember (skip to Q 27)

☐ Yes

26.2 When was the last time you consulted a health provider for your condition?

☐ Within the past month                      ☐ Within the past year

☐ From one (1) to five (5) years ago                      ☐ More than five (5) years ago

☐ Can not remember, not sure

26.3 What kind of health provider(s) did you consult and how many times in the past 5 years [*check several boxes if appropriate*]?

☐ A physician \_\_\_\_\_ times                      ☐ A neurologist \_\_\_\_\_

times

☐ A nurse \_\_\_\_\_ times                      ☐ A traditional healer

\_\_\_\_\_ times

☐ A psychiatrist/psychologist \_\_\_\_\_ times

☐ Other (specify \_\_\_\_\_) \_\_\_\_\_ times

☐ Can not remember, not sure

27 Were you ever treated for this condition?

☐ No (the interview is finished)                      ☐ Can't remember, do not know (interview is finished)

☐ Yes



27.1 When was the last time you used medication for your condition?

☐ Within the past month                      ☐ Within the past year

- ☐ From one (1) to five (5) years ago      ☐ More than five (5) years ago
- ☐ Can not remember, not sure

27.2 What medication was it and how many times in the past year did you have to use some (check several boxes if appropriate)?

- ☐ Phenobarbital \_\_\_\_\_ times
- ☐ Dilantin/Tegritol/ Phentoin Sodium \_\_\_\_\_ times (tick box and underline specific drug name)
- ☐ Valproic acid \_\_\_\_\_ times      ☐ Traditional medicine \_\_\_\_\_ times
- ☐ Other (specify \_\_\_\_\_) \_\_\_\_\_ times
- ☐ Can not remember, not sure

#### **E. Treatment /Deworming**

28 Do you always deworm your pigs?

- ☐ Yes      ☐ No.

28.1 If yes, how often is it done?

- ☐ Once a month    ☐ After every 3 months    ☐ Other (specify)

29 What drugs are used for deworming?

- ☐ Albendazole    ☐ Praziquantel    ☐ Levamisol Chloride    ☐ Ivermectins    ☐ Others

(Specify)

30 What is the source of the drugs?

- ☐ Vet drug shop    ☐ Market vendors    ☐ Veterinarian    ☐ D.V.O    ☐ NGO

31 Why do prefer the drug (named) to others?

☐ Cheap   ☐ Only accessible drug on the market   ☐ Most effective   ☐ Given for free

32 . Do you deworm yourself?   ☐ Yes                      ☐ No.

32.1 If yes, how often is it done?

☐ Once a month   ☐ After every 3 months   ☐ Other (specify).

33. What drugs are used for deworming?

☐ Albendazoles   ☐ Praziquantel   ☐ Ivermectins   ☐ Others (Specify)

34. What is the source of the drugs?

☐ Drug shop   ☐ Market vendors   ☐ Health centre   ☐ Government   ☐ NGO

35. Why do prefer the drug (named) to others?

☐ Cheap   ☐ Only accessible drug on the market   ☐ Most effective   ☐ Given for free

INTERVIEWER: \_\_\_\_\_

DATE OF INTERVIEW: \_\_\_\_\_

## Appendix II: Pig biodata form

1.1 Ear tag ID (identical to sample ID whole blood, serum and faeces).....

1.2 Temperature °C.....

1.3 Pig breed local (1)☐ exotic☐ cross☐ (3)

1.4 Pig age in months.....

1.5 Nose type

1	Straight	2	Curved
---	----------	---	--------

1.6 Ear type

1	Straight	2	Drooping
---	----------	---	----------

1.7 Pig height at withers in cm.....

1.8 Pig chest girth in cm.....

1.9 Head length in cm.....

1.10 Ear length in cm.....

1.11 Trunk length in cm..... Height in cm.....

1.12 Body weight in kg.....

1.13 Number of teats (if sow or gilt).....

1.13b when was the last treatment : MONTH [\_\_]  
YEAR[\_\_]

and what did you give ? [\_\_\_\_]

1= Antibiotics	2= Deworming	3=Multivitamin	4=other specify
----------------	--------------	----------------	-----------------

1.14 Date when last the pig was sick ? MONTH [ \_\_\_\_]  
YEAR[\_\_\_\_]

1.15 If yes, what were the symptoms ?

1= diarrhoea	2= lack of appetite	3=dullness	4=swaying gait	5=skin flash	6=respiratory problems
7=vomiting	8=coughing	9= shivering	10=foaming at mouth	11=wounds	12=Other
99 = Never					

1.16 Does the pig belong to this household ? 1=yes ☐ 2=no ☐

1.17 Where did you get the pig from ?

1= neighbour	2= relative	3=other farm	4=pig trader	5=NADDS	6=NGO
7=farmer organization or self help group	8= friend	9=youth group	10=born in the HH	11= other (specify)	

1.18 How did you get it ?

1= purchased	2= payment for boar service	3= Developemnt project/NAADS	4= loan	5=other (specify)
--------------	-----------------------------	------------------------------	---------	-------------------

1.19 If purchased, how much did it cost in Shs ?

1.20 When did you enquire (do you mean acquire?) this pig ?  
month/year.....

1.20.1 Contact or pig source (can you give us more information to help us find the person you got this pig from, so that we can also interview them about pig keeping ?)

First name	Vilage name	Contact (tel..)	Distance (1=<1km ; 2=1-5 km ; 3=5-10km; 4=>10 km)

1.21 Pig category

1=weaner (> 3 months)	2= sow	3= entire boar	4=castrated boar	5=piglet (if mother not present)
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### **Appendix III: Consent form for participants**



INTERNATIONAL  
LIVESTOCK RESEARCH  
INSTITUTE

#### **Smallholder Pig Value Chain Development Project in Uganda: PIG Health and farmers livelihoods**

Information sheet to be explained to study participants:

Diseases constitute a main constraint to pig production in Uganda. This study aims to determine the burden of diseases in pigs Uganda.

You are kindly invited to take part in the study. We will ask you questions about pig management and pork consumption before we collect blood and stool from the sick or healthy pigs on your farm.

We will collect some blood and stool samples from some of the pigs in your house by bleeding through the jugular vein and also collect stool by introducing fingers in the anus of the pig. For each animal, we will use new needles and gloves so no diseases can be transmitted from one pig to another. We will then tag your animal on the ear for tracing forward to the abattoir. This procedure is not painful to the pigs and is not associated with any risk of injury.

Samples collected and germs isolated from this study will be stored in our freezers at ILRI laboratories in Nairobi, Kenya, and may be used for future studies.

The information you provide to us and the samples we take will be de-identified so that they are anonymous. This means that we will not keep your name with the information and samples. We will mark the information and samples with a barcode instead of your name.

You can withdraw from this study at any time. Participation in the study is entirely voluntarily and will not interfere with standard assistance that you or your animals could receive from the project.

Do you have any questions about the study?

Do you agree to join the study? If you agree the consent form will be read to you before you sign the form.

The field assistant will countersign the consent form to indicate that the farmers understood the explanation and freely gave their consent.

## **Consent form for study participants**

I understand I have been asked to take part in a study in which blood and stool samples will be collected from my pigs. I will also answer questions about my pig management and pork consumption.

I understand that if I agree to take part in the study blood and stool will be collected from my pigs and then the targeted pigs will be tagged on the ear. It has been explained to me that this procedure is not painful to the animals and is not associated with any risk of injury.

I understand that participation in this study is entirely voluntary and will not interfere with standard assistance I or my pigs would have received from the project. I understand that I can leave the study at any point without this interfering with access of my animals to healthcare service if they become sick in any way.

I understand that samples collected and germs isolated from this study will be stored at ILRI laboratory freezers and will be used for future studies.

The researcher can use photographs of my farm or family to tell other people good, positive stories and will give me a copy of any photographs they use in case I have requested for. For these photographs,

☐ I DO want the researcher to tell other people my name

☐ I DO NOT want the researcher to tell other people my name

I have had an opportunity to ask the ILRI field worker who explained the study to me and answers to any questions that I had about the study.

I agree to join the study.

Name.....Signature or  
thumbprint.....

ID .....Village name..... Sub-  
county..... District.....

Telephone number (if  
available).....  
.....

Witnessed by  
name.....Title.....  
.....

---

I, ....., confirm that I have explained the  
nature of the study to..... as set out

in the study protocols, that s/he understood what I said, had an opportunity to ask questions and freely gave his/her consent for him/her to join the study.


NAME OF FIELD

WORKER.....SIGNATURE.....


.....

DATE       |\_|\_|/|\_|\_|/|\_|\_|\_|\_|

## Appendix IV: Ethical review recommendation letter



**MAKERERE UNIVERSITY**  
COLLEGE OF VETERINARY MEDICINE,  
ANIMAL RESOURCES & BIOSECURITY  
SCHOOL OF BIOSECURITY, BIOTECHNICAL AND LABORATORY SCIENCES (SBLs)



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Email: [principal@covab.mak.ac.ug](mailto:principal@covab.mak.ac.ug)  
Website: [www.covab.mak.ac.ug](http://www.covab.mak.ac.ug)

---

Your Ref :

Our Ref :

Date : 15/03/2013

No. VAB/REC/13/104

**RESEARCH AND ETHICS COMMITTEE REVIEW AND ENDORSEMENT**

Statement from the Institutional Ethical Review Board:

The REC only accepts for review and approval, research proposals that have been found both scientifically and ethically acceptable in accordance with guidelines on Institutional Ethical Review Boards.

We the **Institutional Ethical Review Committee** established by  
COLLEGE OF VETERINARY MEDICINE, ANIMAL REOSURCES AND BIOSECURITY  
do certify that we have reviewed the research proposal entitled

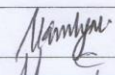
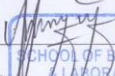
**"Characterization of the Pig Production Systems and the Marketing Chain with  
Regard to the Possible Influence on T. solium Cysticercosis transmission in  
Uganda"**

submitted by

**Dr. Joseph Kungu**

We attest to scientific and ethical merit of this study and competency of the investigator(s) to conduct the research on animals and their samples and do hereby recommend the proposal to the Uganda National Council for Science and Technology (UNSC) for approval.


**SIGNATURES**

	Name	Signature	Date
<b>Ethics Committee Representative</b>	Dr. Clovice Kankya		15/03/2013
<b>Head of Ethics Committee</b>	Assoc. Prof. David Owiny		15/03/2013

Contact Tel. No: +256-772-443-658

Email address: [dowiny@vetmed.mak.ac.ug](mailto:dowiny@vetmed.mak.ac.ug), [owinyd@gmail.com](mailto:owinyd@gmail.com)

OFFICIAL STAMP OF INSTITUTION



*Vision :To be a leading and productive academic institution in strategic innovations and services*

## **Appendix V: Manuscripts and their status**

1. Kungu J M, Ejobi F, Ocaido M, Grace D, Dione M M. Status and predisposing factors for *Taenia solium* cysticercosis in developing countries. Published in International Journal of One Health.
2. Kungu J M, Ejobi F, Ocaido M, Roesel K, Grace D, Dione M M. Spatial distribution of pork retail outlets and potential for transmission of food-borne pathogens in Kampala district, Uganda. Submitted to Onderstepoort Journal of Veterinary Research.
3. Kungu J M, Ejobi F, Ocaido M, Grace D, Dione M M. Seroprevalence of *Taenia solium* cysticercosis in pigs in Masaka, Mukono and Kamuli districts, Uganda. Accepted for publication in Acta tropica Journal.
4. Kungu J M, Ejobi F, Ocaido M, Grace D, Dione M M. Risk factors for *Taenia solium* cysticercosis in Masaka, Mukono and Kamuli districts, Uganda. In preparation for submission.
5. Kungu J M, Ejobi F, Ocaido M, Grace D, Dione M M. Perceptions and practices of farmers on *T. solium* cysticercosis and its control in Uganda. In preparation for submission.